Equilibrium Beach Profile Measurement and Sediment Analysis: Mustang Island, Texas

Major Report

by

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Abstract

This engineering report describes the measurement techniques and results of an equilibrium beach profile survey and sediment analysis conducted by Texas A&M University, Ocean Engineering Program, at Mustang Island, Texas on September 27, 1997. The main objective of the project was to obtain an accurate equilibrium beach profile at a location on Mustang Island, and to compare the actual profile to a predicted profile. The predicted profile is based on the median grain size diameter of sediment samples taken from the dune crest to approximately 4000 ft offshore.

The survey was accomplished using an electronic total station with a standard surveying rod on land, and the underwater profile was measured with a "sled" towed behind a boat. A triple prism was attached to both the top of the rod and sled. The sled is an aluminum and steel structure equipped with two 12 ft long skids and a 36.5 ft mast.

The predicted profiles are based on two methods. One method uses Dean's (1997) equation for equilibrium beach profiles, $z = Ax^{2/3}$, where z is the water depth, A is the profile scale factor related to the sediment fall velocity, and x is the distance offshore. The other method involves a more complex analysis described by Dean and Dalrymple (1996), which accounts for a variation in sediment size and profile scale factor, A, in the offshore direction. Both methods are described and compared in this report. This data will also be used by Dr. R. G. Dean of the University of Florida in a study he is conducting on equilibrium beach profile prediction.

Dedication

This report is dedicated to Jill, Amber, and Sammi for all of their love, patience, and assistance.

Acknowledgments

I would like to thank my committee members, Dr. Billy L. Edge, Dr. Robert E. Randall, and Dr. Robert O. Reid. Their guidance through this project is greatly appreciated. Special thanks to Dr. Daniel T. Cox, and Dr. Kelly L. Rankin for their assistance and technical support both in and out of the field. Thanks are also expressed to Dr. James S. Bonner and James Risso for their boat, supplies, and experience, and to Dr. Robert F. Bruner for the surveying equipment. Finally, I would like to thank John Reed, Michael Schrepfner, and my working crew: Steven Howard, Bill Hobensack, Ben Cole, Monty Conner, and Sean Kelley.

Table of Contents

List of Figures

List of Tables

Introduction

Project Mission

The main objective of this project was to obtain an accurate equilibrium beach profile at a location on Mustang Island, and to compare the actual profile to a predicted profile. The location of Mustang Island can be seen in Figure 1. The predicted profile is based on the median grain size diameter of sediment samples taken at the location from the dunes to approximately 4000 ft offshore. This project will use relationships described by Dean and Dalrymple (1996) in the analysis of the sediment grain sizes and predicted beach profiles.

There are two relationships for predicting equilibrium beach profiles which will be compared in this report. One relationship involves predicting the beach profile based on one sediment grain size obtained from the mid-shore or foreshore region of the beach. The other relationship accounts for variations in sediment grain size in the offshore direction. The later relationship is more realistic because it accounts for the natural hydrodynamic sorting of sand sizes, where sand sizes become finer in the offshore direction (Dean & Dalrymple, 1996).

This project involved two days of field work on Mustang Island, Texas. The data collection was two-fold. A survey crew collected all data pertaining to the beach profile. A dive crew collected sediment samples in the offshore direction up to a depth of about 35 ft. The data collection techniques and results from both crews are described in detail in this report.

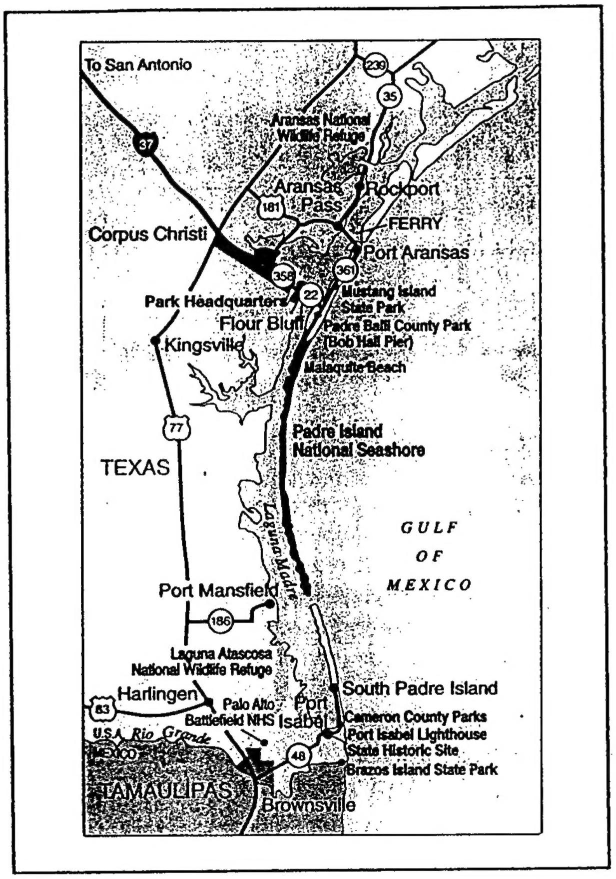


Figure 1. Location of Mustang Island State Park in relation to Corpus Christi, Texas.

This data will also be used by Dr. Robert G. Dean of the University of Florida in a "blindfolded" study he is conducting on equilibrium beach profile prediction. The results of the sediment analysis and location of samples will be sent to Dr. Dean. Dr. Dean will then calculate and plot a predicted equilibrium profile based on the sediment grain size from a FORTRAN program he is writing. A copy of this predicted profile will be returned, and the measured profile will then be sent to Dr. Dean.

Equilibrium Beach Profiles

A beach profile is the variation in the vertical change of the sea floor with the distance offshore, and it is measured perpendicular to shore. A beach profile is synonymous to a topographical map for the sea. The concept of an equilibrium beach profile came about in 1977 with the research of Dr. Robert Dean of the University of Florida. Dean examined over 500 beaches from the Atlantic and Gulf coasts and developed a relationship describing the water depth as being proportional to the distance offshore to the two-thirds power for a given sediment grain size.

The predicted profiles are based on two methods. One method is simply using Dean's (1977) equation for equilibrium beach profiles, $z = Ax^{2/3}$, where z is the water depth, A is the profile scale factor related to the sediment fall velocity, and x is the distance offshore. The other method involves a more complex analysis described by Dean and Dalrymple (1996), which accounts for a variation in sediment size and profile scale factor, A, in the offshore direction. This method is more realistic because it accounts for the natural sorting of sand sizes from coarser to finer diameters in the cross-shore direction. Both methods are described and compared in this report.

The survey of the beach profile was divided up into two sections: land and sea. The land profile was measured using an electronic total station and a standard surveying rod with a triple prism attached. The underwater profile was measured with a "sled" towed behind a boat. A triple prism was also attached to the top of the sled. The sled was originally designed and built by Rudolph Pesek, an undergraduate student at Texas

A & M, as his senior design project. The sled is an aluminum and steel structure equipped with two 12 ft long skids and a 36.5 ft mast.

Before this project, the sled had only been tested in a trial run at Lake Bryan near Bryan, Texas. The test consisted of setting up the sled and successfully towing it into the lake and back. There was no need for survey equipment because the goal of the test was to observe the sled's ability to be towed. It was found that the sled behaves well in tow, but it requires a boat with more that 150 hp to be towed successfully.

Sediment Grain Size

Sediment grain size varies across a beach in the cross-shore direction. Sediment median grain sizes become smaller with a decrease in wave intensity. This decrease in sediment grain size also correlates with a decrease in beach face slope (Bascom, 1951). It has also been shown that the decrease in beach face slope with smaller diameter grain sizes also continues in the offshore direction.

Sediment samples were taken along the beach profile in the cross-shore direction from the dunes to about 4000 ft offshore. A sieve analysis was conducted on these samples and the grain size distribution was determined for each sample. The samples taken in the cross-shore direction will show the variation in sediment size. The beach slope variation will also be compared to the distance offshore, and the beach slope will also be correlated to the median sediment diameter, d_{50}.

Background Theory

Surveying Techniques for Equilibrium Beach Profiles

Beach profile measurement techniques usually involve an amphibious operation where the surveyor must survey on land and at sea. Typically, a land survey is completed using land surveying techniques. That data is combined with an offshore survey which measures the underwater beach profile. Figure 2 illustrates these amphibious surveying techniques. Although land surveying techniques are common, surveying an underwater beach profile is still a challenging and developing field.

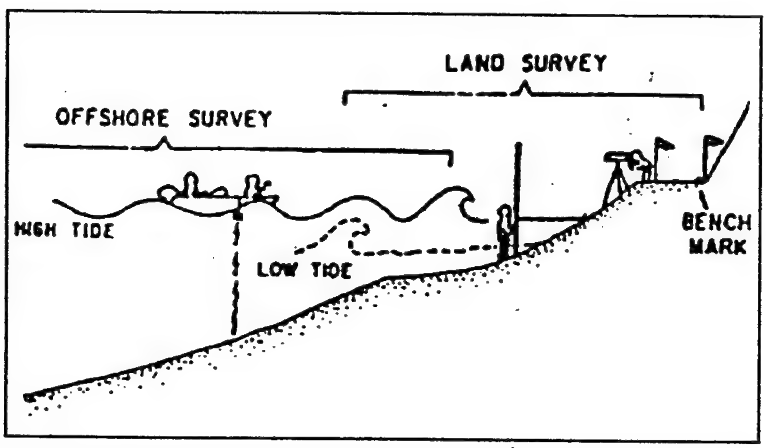


Figure 2. Beach Profile Survey Technique (Dean & Dalrymple, 1996, from Nordstrom and Inman, 1975)

Offshore profiles can be completed using a number of methods. The most common method is obtained by using a survey boat equipped with a positioning system such as LORAN-C or Global Positioning System (GPS), and a fathometer. The boats

position is later correlated with the depth measurements to give the beach profile. A correction to this profile must be applied for all tidal bodies of water which accounts for the tidal water level. The effect of waves are generally accounted for by "smoothing out" the profile and using only the average depth values. The disadvantage to this method is that true irregularities of the beach profile may be lost using this method (Dean & Dalrymple, 1996).

Another method for obtaining offshore beach profiles is the use of vehicles like the Coastal Research Amphibious Buggy (CRAB) of the U.S. Army Corps of Engineers Coastal Research Center shown in Figure 3. The CRAB is a massive 35 ft high, 29.5 ft long tripod equipped with a Volkswagen industrial gasoline engine which drives an Eaton hydraulic pump. The hydraulic pump powers the three liquid filled tires which are over 5 ft in diameter. The CRAB is equipped with a prism cluster, and uses a land based Zeiss Elta-2 electronic total station to obtain profile data (Birkemeier & Mason, 1984).

The CRAB can operate in rough seas and it also eliminates the need for tide measurements. It is also equipped with various scientific instruments which measure wave height, current velocities, and it can take core samples. Despite the obvious advantages of the CRAB, it also has a few astounding disadvantages. The most obvious is the CRAB's lack of portability. The CRAB's operational weight is 18,000 lbs and minimum transport weight is 15,000 lbs. It is usually transported by a CH-5 Chinook helicopter, but it meets the helicopter's maximum payload capacity of 15,000 lbs. The

other obvious drawback is the CRAB's high initial cost (Birkemeier & Mason, 1984).

The CRAB would definitely be a welcome addition to any coastal engineering program, however, very few research institutions or universities can afford the high initial cost or maintenance for such a vehicle. Therefore, there must be a cheaper alternative for obtaining equilibrium beach profiles offshore.

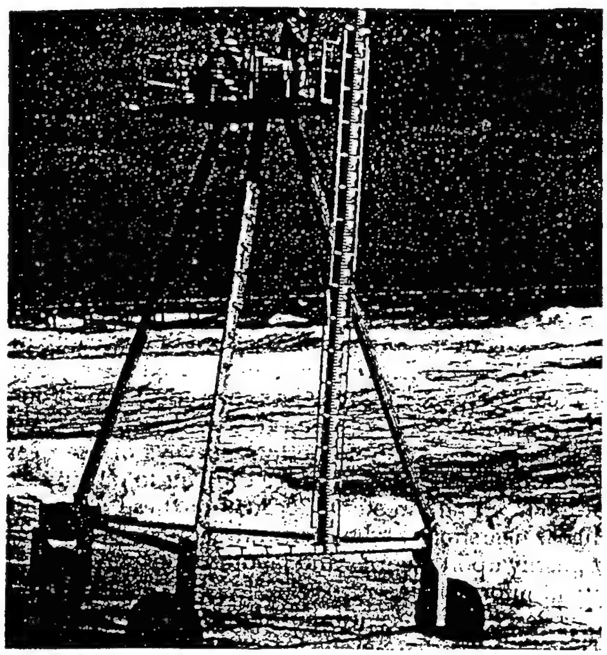


Figure 3. Coastal Research Amphibious Buggy (Birkemeier & Mason, 1984)

One alternative to using a boat with a fathometer, or a CRAB like vehicle is the use of an amphibious sea sled which can be towed offshore by boat from the dry beach. This method of obtaining equilibrium beach profiles was used in this research project. A general definition of a sled is a structure which slides across the sea floor on skids and supports a surveying prism or other positioning device such as a GPS antenna. The sled

used in this project is an aluminum and steel structure equipped with a 36.5 ft mast, two 12 ft long skids, and supports a triple prism atop the mast. Figure 4 shows the basic dimensions of the Texas A & M University sled, and Figure 5 shows the height of the structure. Advantages of the sled are low initial and maintenance costs, ease of portability and operation, and accuracy of results. The major disadvantage is the need for a boat to tow the sled offshore.

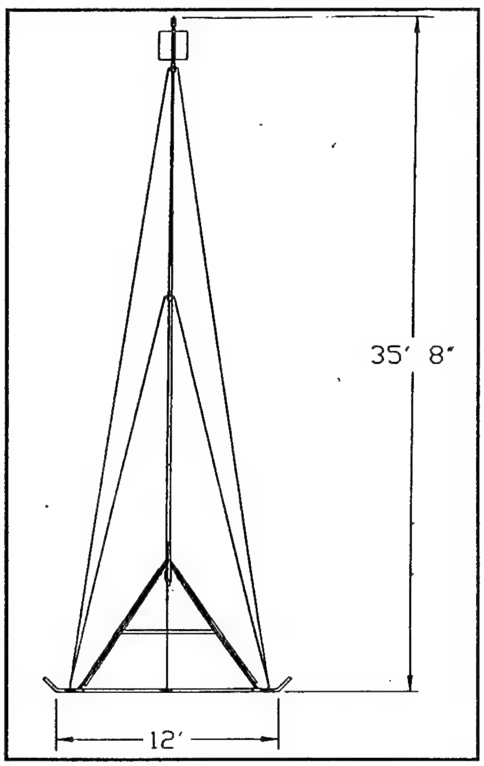


Figure 4. Diagram of basic sled dimensions.

Figure 5. Sled towering over survey site.

Equilibrium Beach Profile Prediction

The development of an equilibrium beach profile theory has been a major advance in the field of beach nourishment design. It has given coastal engineers the ability to predict the equilibrium shape of beach nourishment projects. Equilibrium beach profile theory also assists in calculating the amount of sediment that will be needed to nourish these beaches.

The concept of an equilibrium beach profile was first identified by Bruun in 1954. In field studies of beach profiles off the coasts of California and Denmark, Bruun noticed that the beach profiles were well represented by a two-thirds power curve. Dean (1977) further examined this concept in a study of 502 beach profiles from the east coast of the United States and Gulf of Mexico. Dean found that each profile followed the generalized power law of $z = Ax^{2/3}$, where z is the depth of the profile below the mean water level, A is a profile scale factor, and x is the distance offshore. Dean also found that this two-thirds power law relationship agreed remarkably well with a relationship derived from examining the destructive forces on a beach (Dean & Dalrymple, 1996).

The equilibrium beach profile theory developed by Dean is based on the assumption that the dominant destructive force acting on a beach is turbulence caused by breaking waves. The development of the theory is based on the concept that a sediment of a given grain size is able to withstand a given level of wave energy dissipation per unit volume. The first step in deriving an equation for the equilibrium beach profile is to develop an equation for the conservation of energy in the surf zone.

This is done by setting the change in wave energy flux over a certain distance equal to the water depth multiplied times the uniform energy dissipation rate per unit volume for a given grain size (Dean & Dalrymple, 1996). This relationship is show in equation 1.

$$\frac{dF}{dx}=zD \qquad \text{(Eq. 1)}$$

The wave energy flux is given by the following equation:

$$F=\frac{1}{8}\rho g H^{2}\sqrt{gz} \qquad \text{(Eq. 2)}$$

where ρ is the density of sea water, g is the acceleration due to gravity, k is a constant for the wave breaking index, and z is water depth (Dean & Dalrymple, 1996).

The next step is to take the derivative of the wave energy flux and simplify the energy dissipation rate per unit volume from equation 1 to get equation 3 (Dean & Dalrymple, 1996).

$$D=\frac{5}{16}\rho g^{3/2}k^{2}z^{1/2}\frac{dz}{dx} \qquad \text{(Eq. 3)}$$

Finally, the equation representing the equilibrium beach profile is calculated by integrating the water depth, z, with respect to the distance offshore, x. Equation 4 is the result of this derivation for an equilibrium beach profile equation (Dean & Dalrymple, 1996).

$$z(x)=\left(\frac{24D}{5\rho g\sqrt{g}k^{2}}\right)^{2/3}x^{2/3}=Ax^{2/3} \qquad \text{(Eq. 4)}$$

where A is defined as the profile scale factor which is a function of the energy dissipation and the grain size of the beach. As mentioned before, this equation for representing an equilibrium beach profile derived from the dominant destructive forces acting on a beach agrees remarkably well with the empirical relationship described by both Bruun(1954) and Dean (1977).

There are many methods for predicting equilibrium beach profiles. Two of these methods are discussed and applied in this report. The first relationship involves predicting the beach profile based on one sediment grain size obtained from the mid-shore region of the beach. The second relationship accounts for variations in sediment grain size in the offshore direction. The first method will be referred to as method 1, and the second method as method 2. The later relationship is more realistic because it accounts for the natural hydrodynamic sorting of sand sizes, where sand sizes become finer in the offshore direction (Dean & Dalrymple, 1996).

The first method in determining the equilibrium beach profile is the simpler of the two. According to Dalrymple and Dean (1996), for an equilibrium beach profile, the depth is proportional to the profile scale factor, "A", multiplied by the distance offshore to the two-thirds power. Dean (1977) described the relationship for the equilibrium beach profile using the following equation which was derived earlier as equation 4 (Dalrymple & Dean 1996):

$$z = Ax^{2/3} \qquad \text{(Eq. 5)}$$

where z is the water depth (m), A is the profile scale factor ($m^{1/3}$) related to the sediment fall velocity, and x is the distance offshore (m).

The profile scale factor ,"A", was related to the sand diameter, d, by Moore (1982). Dean (1987) further related the profile scale factor, "A", directly to the fall velocity (m/s), *w*, in the equation (Dalrymple & Dean, 1996):

$$A = 0.067w^{0.44} \qquad \text{(Eq. 6)}$$

The fall velocity (cm/s), *w*, was related to the median sediment diameter (mm), d_{50}, by Hallermeier (1981) with the equation (Edge, 1997):

$$w = 14d_{50}^{1.1} \qquad \text{(Eq.7)}$$

The relationships between the sediment fall velocity, *w*, sediment size, d, and profile scale factor, A, can be seen in Figure 6.

As mentioned before, method 1 for predicting equilibrium beach profiles does not take into account the cross-shore variation in sediment grain size. However, the sediment grain size does vary in the cross-shore direction, and the slope of the beach also varies with the change in sediment diameter. For this reason, Dean and Dalrymple (1996) describe an alternate method for predicting equilibrium beach profiles which takes into account the variation in sediment grain size diameter. This method is referred to as method 2.

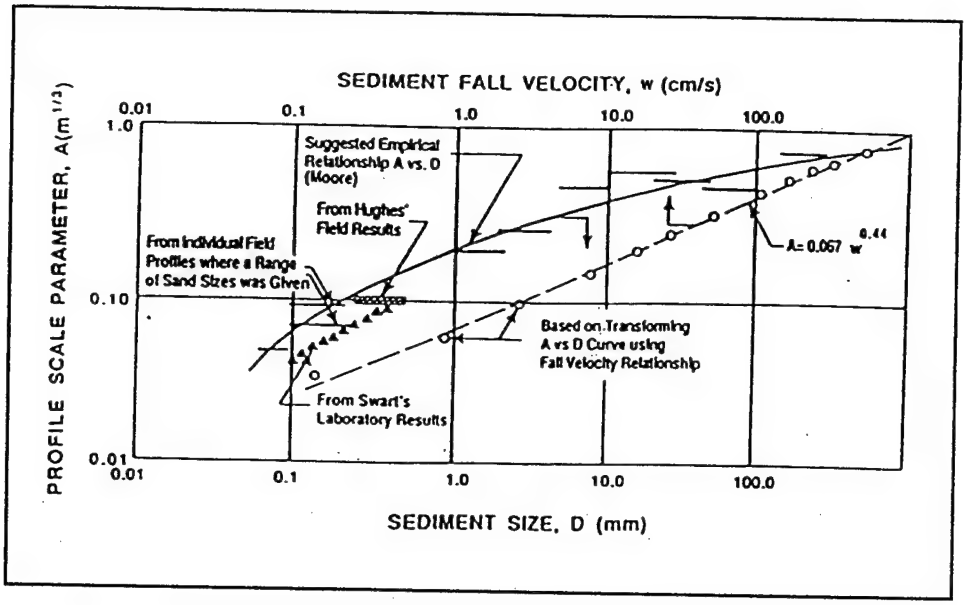


Figure 6. Profile Scale Factor, A versus Sediment Diameter, d, and Fall Velocity, *w* (Dean, 1987; adapted in part from Moore, 1982)

Method 2 assumes that the profile scale factor, A, varies linearly between two adjacent locations. Dean and Charles (1994) developed a relationship for this variation in profile scale factor between two known samples. This relationship is described in the equation (Dean & Dalrymple, 1996):

$$A(x)=A_n+\frac{A_{n+1}-A_n}{x_{n+1}-x_n}(x-x_n) \quad \text{(Eq. 8)}$$

for $x_n < x < x_{n+1}$. So, between any two sample locations where the profile scale factor, A, is known, an estimated profile scale factor can be calculated.

Furthermore, if a profile scale factor is also known between two points, then the beach profile between those two points is expressed by the equation (Dean &

Dalrymple, 1996):

$$z(x)=(z_n^{3/2}+A_n^{3/2}(x-x_n))^{2/3} \qquad \text{(Eq. 9)}$$

for $x_n < x < x_n$.

With these relationships, the equilibrium beach profile can be calculated across a beach where the sediment grain size varies in the cross-shore direction.

Sediment Grain Size Analysis

In order to determine the profile scale factor, A, the median sediment grain size, d_{50}, is needed. One method of determining the median grain size along with many other sediment size distribution parameters is to sort the sediment into its various size components based on the sediment diameter by the use of sieves. The methods for sieving sediment samples will be discussed in detail later in this report. This section, however, will describe other sediment distribution parameters not already mentioned above which are commonly used to describe sediment samples.

Other sediment size distribution parameters such as the standard deviation and skewness of the sediment sample are useful in describing certain characteristics about a sediment sample. These calculations are based in the phi unit scale proposed by Krumbein (1936). The phi unit is defined in equation 10 below (Shore Protection Manual, 1984):

$$\phi=-\log_2(d) \qquad \text{(Eq. 10)}$$

where ϕ is the sediment size in phi units, and d is the sediment grain diameter in millimeters.

The standard deviation of the sample is used to determine how well a sample is sorted around the mean grain size. Inman (1952) defined the standard deviation to be (Shore Protection Manual, 1984):

$$\sigma=\frac{\phi_{84}-\phi_{16}}{2} \qquad \text{(Eq. 11)}$$

where σ is the standard deviation of the sample, ϕ_{84} is the grain size that is coarser than 84 percent of the sample by weight, and ϕ_{16} is the grain size that is coarser than 16 percent of the sample by weight. The values of ϕ_{16}, ϕ_{84}, and ϕ_{50}, are typically obtained from a cumulative percent coarser plot as seen in the example size distribution of Figure 7.

A standard deviation equal to zero represents a perfectly sorted sample, and for a well-sorted sample the standard deviation is around 0.5. A well-sorted sample is poorly-graded meaning that its particles are close to a typical size. Conversely, a well-graded sample is poorly-sorted.

The skewness of the sample indicates how well the sediment sizes are distributed about the mean size of the sample. The skewness was defined by Inman (1952) to be (Shore Protection Manual 1984):

$$\alpha=\frac{M_{\phi}-M_{d\phi}}{\sigma_{\phi}} \qquad \text{(Eq. 12)}$$

where a is the skewness of the sample, M_ϕ is the mean phi size as calculated below with equation 9, $M_{d\phi}$ is the median phi size obtained from the value of d_{50} on the percent coarser plot, and σ_ϕ is the standard deviation in phi units.

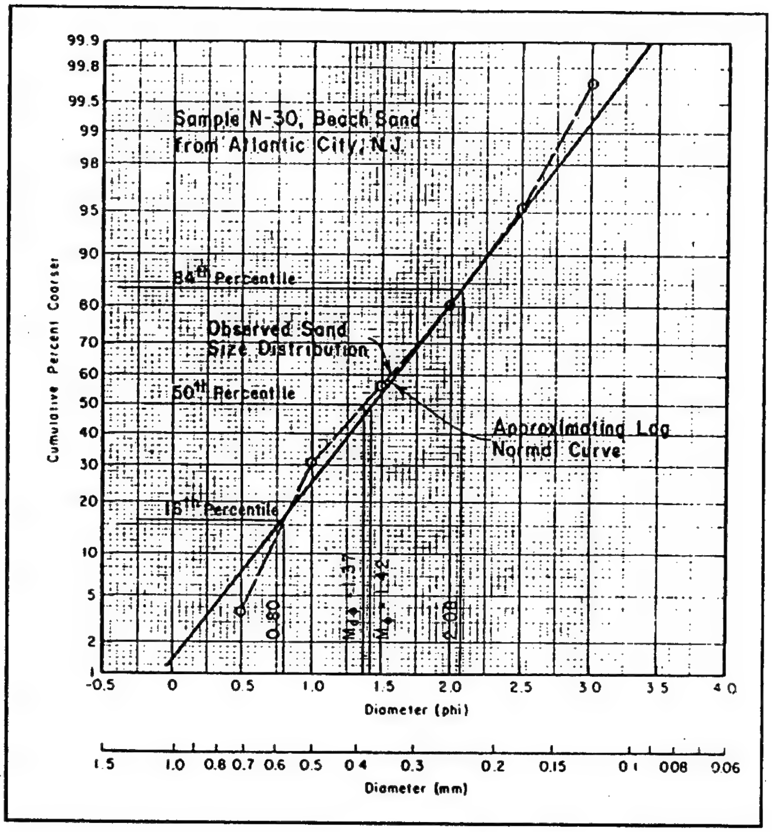


Figure 7. Example size distribution
(Shore protection Manual, 1984)

The mean phi size, M_ϕ, was defined by Otto (1939) and Inman (1952) to be (Dalrymple & Dean 1996):

$$M_\phi = \frac{\Phi_{84} + \Phi_{16}}{2} \tag{Eq. 13}$$

A sample that has a perfectly symmetric distribution about the mean has a skewness of zero. A negative skewness indicates that the sample is skewed towards the smaller phi sizes, or larger grain sizes. According to Dalrymple and Dean (1996), Duane (1964) showed that a negative skewness indicates an erosive environment where the finer materials have been removed from waves or currents. On the contrary, a positive skewness indicates a depositional environment.

Methodology

Equilibrium Beach Profiles

The equilibrium beach profiles measured in this project were completed by matching the results of a land survey with an offshore survey. Two separate profiles were measured, and they were labeled profiles A & B. Profile A was located about three miles northwest of the "Fish Pass" jetties on Mustang Island. The jetties are located just north of Mustang Island State Park and south of the first beach access road after the park. Figure 8 shows the location of the "Fish Pass " jetties and approximate location of profile A. For profile A, sediment samples were taken along the profile. Profile B was completed about 300 ft south of profile A, and its main purpose was to verify the results of profile A.

The land survey was completed with the use of an electronic total station and a standard surveying rod with a triple prism cluster attached to the top. At the time of the survey, there was no known benchmark data or geographical datum to reference the beach surveys. Therefore, a 5 ft long, 1 inch diameter steel pipe was hammered into the dune as a permanent marker for the survey and assumed to be origin of the survey. Range poles were also set up to keep the rod man and sled aligned with the profile. The rod was then walked out from the dunes in the offshore direction until the rod man could not stand up in the water without swimming. Meanwhile, the electronic total station delivered horizontal distance measurements, and horizontal and vertical angles. Figure 9 shows the survey crew operating the electronic total station. The readings were later

converted into X, Y, and Z coordinates of position. This method was used to compile a land survey for both profile A & B.

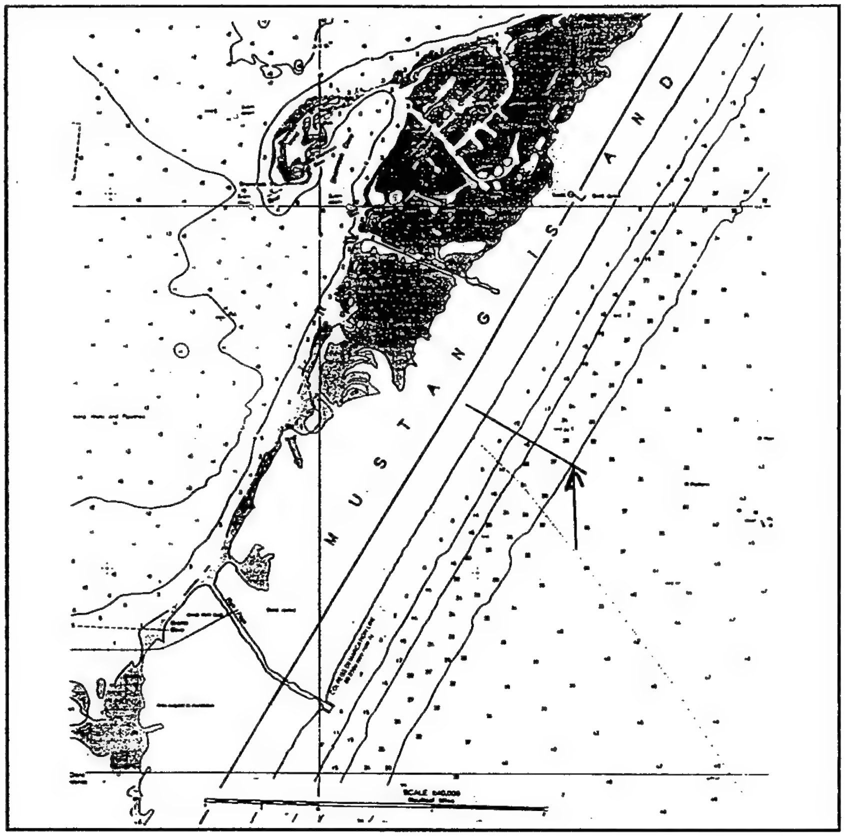


Figure 8. Approximate location of beach survey on Mustang Island.

The offshore survey involving the sled began in the surf zone where the sled was towed offshore by boat. The sled is a 400 lb aluminum and steel structure equipped with a 36.5 ft mast, two 12 ft long skids, and supports a triple prism atop the mast. It requires a relatively powerful tow boat with a shallow draft which allows it to come close to shore in shallow water. The boat used to tow the sled in this project was

charted out of Port Aransas, Texas. The boat was a 25 ft twin hulled Seacat equipped with two 150 hp engines. Its draft was about 1.5 ft which allowed it to come relatively close to shore. The attachment of tow lines and movement of equipment and personnel from the beach to the tow boat was completed with the use of a Zodiac boat.

Figure 9. Survey crew operating electronic total station.

Once the sled was ready, the first offshore profile, profile A, began. The tow boat pulled the sled offshore until it reached a depth of about 35 ft. Figure 10 shows the sled beginning a survey in the surf zone. Along the way, the boat stopped at designated locations so a diver could collect sediment samples. The locations of the sediment samples were set to be at about every one meter of depth change. To aid in identifying

every one meter depth change, orange marks were painted on the sled mast at one meter intervals. Once the sled reached a depth of 35 ft, the boat towed the sled to the next profile location approximately 300 ft south. The sled was then towed from offshore toward the beach for profile B.

The assembly of the sled involves at least four people and takes about five hours. The details of the assembly are not discussed in detail in this report. However, Appendix C contains all the pertinent diagrams and assembly instructions to the sled. Appendix A also contains a check list of materials and list of contacts.

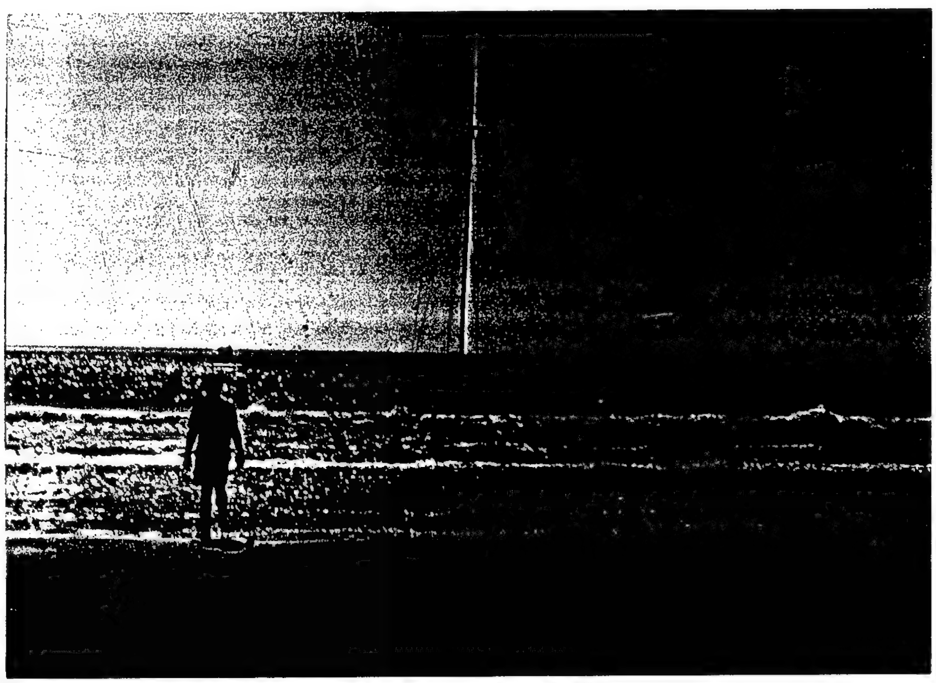


Figure 10. Sled entering surf zone.

Sediment Collection

Sediment samples were taken along the beach profile at 13 different locations.

The method of obtaining the sediment samples involved a SCUBA diver equipped with a tin coffee can for gathering the sample. The diver "rode" the sled underwater from the beach to a distance of about 4000 ft offshore. At designated locations, the diver scooped up about 1 kilogram of sediment into the coffee can. These sample locations are illustrated in Figure 11. The diver then surfaced to give the sample to an awaiting Zodiac boat. In the boat, the sample was transferred to a plastic bag where it was labeled.

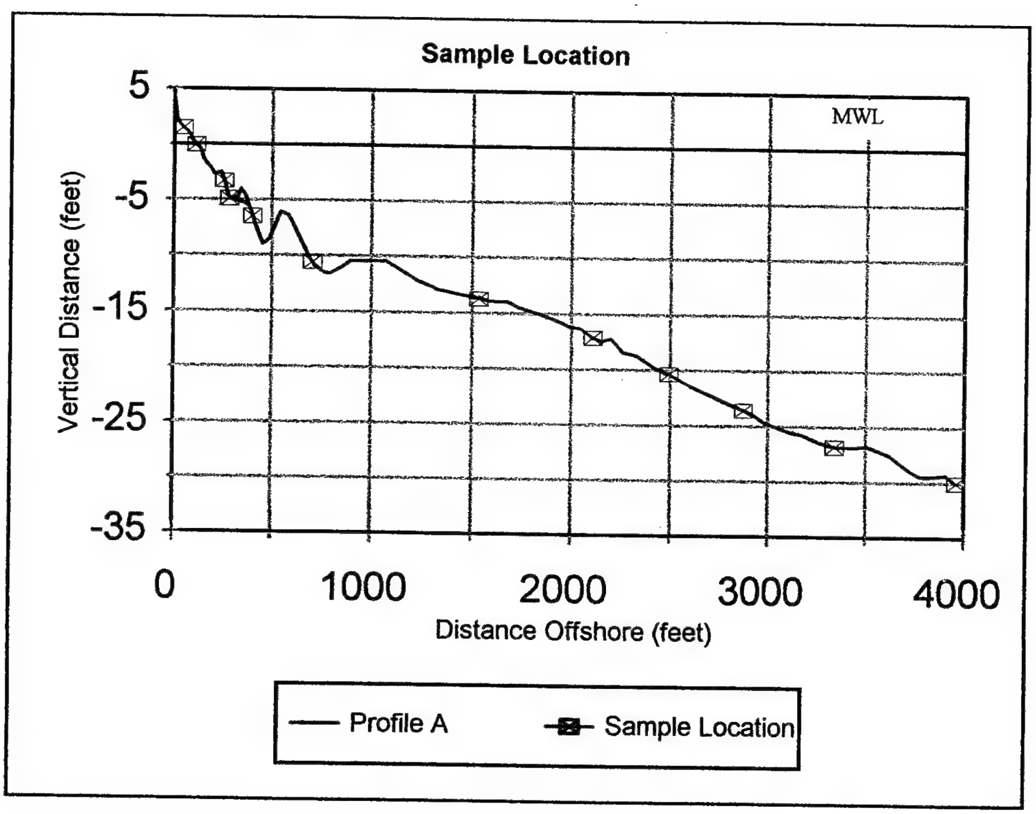


Figure 11. Sample Location.

The method of "riding" the sled was not the original plan for sediment collection. The original plan involved the Zodiac boat being the launch platform for the diver. The diver would ride in the Zodiac between dives, and then dive at each location from the surface. This method would have required the diver to make 10 surface dives and to pull his equipment out of the water and into the Zodiac the same number of times in about an hour and a half period. After two attempts at this method, it proved to be too strenuous for the diver. Therefore, the diver submerged after delivering each sample to the Zodiac and held onto the sled underwater while it was towed by the boat. This proved to be less strenuous on the diver, and also provided a bird's eye view of the sled's behavior underwater. The diver observed that the sled's bow is lifted while in tow and because of this the sled does not "dig" into the sea floor. Figure 12 shows the diver in action.

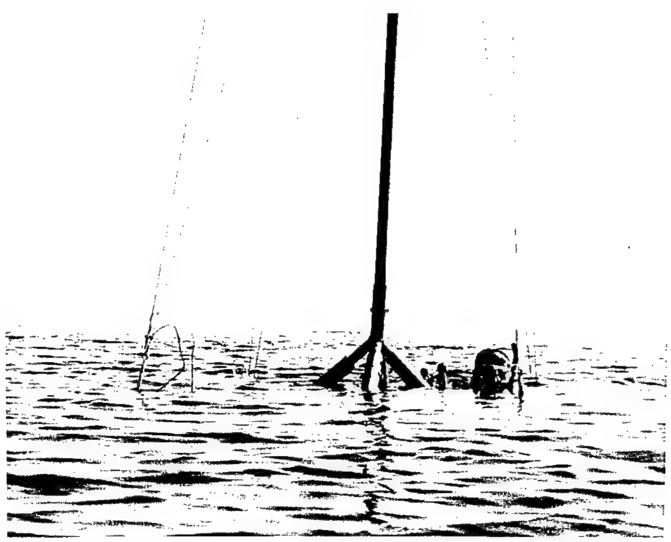


Figure 12. Diver, Erick Knezek, preparing to collect sediment samples

Sieve Analysis

The sediment analysis was completed using U.S. standard sieves. A sieve analysis involves sorting the sediment sample in sieves stacked in order from largest to smallest openings. First, each sample was placed in an oven and baked at 500° F for 30 minutes to remove all moisture. Next, the sieves were stacked in order of decreasing opening size (largest opening on top). Sieve numbers 60, 80, 100, 120, 140, 170, 200, and a collection pan were used to sort the sediment. These sieve numbers correspond to the number of mesh openings per inch of area on the sieve. The corresponding phi units for these sieves were 2.00, 2.47, 2.74, 3.00, 3.24, 3.47, and 3.74.

The Shore Protection Manual (1984) states that standard sieve openings vary by 0.25 phi increments, but recommends that beach sand can be adequately analyzed using 0.5 phi increments. The sieve openings in this analysis vary by about 0.25 phi increments which gives a more definitive sediment distribution. The relationship between the sieve mesh size, and corresponding sediment diameters in phi units and millimeters can be seen in Figure 13.

Each sample was weighed using an electronic scale before and after each sorting. Once each sample was dried and weighed, a 400 gram sample was placed in the number 60 sieve. The sieve stack was then placed on an electric shaker on high speed for ten minutes to sort each sample. After sorting, the sediment remaining in each sieve was weighed individually to determine the grams retained. From this data, the cumulative percent coarser for each sieve diameter was determined and plotted. From the plot, the

values of ϕ_{16}, ϕ_{84}, and ϕ_{50}, were obtained.

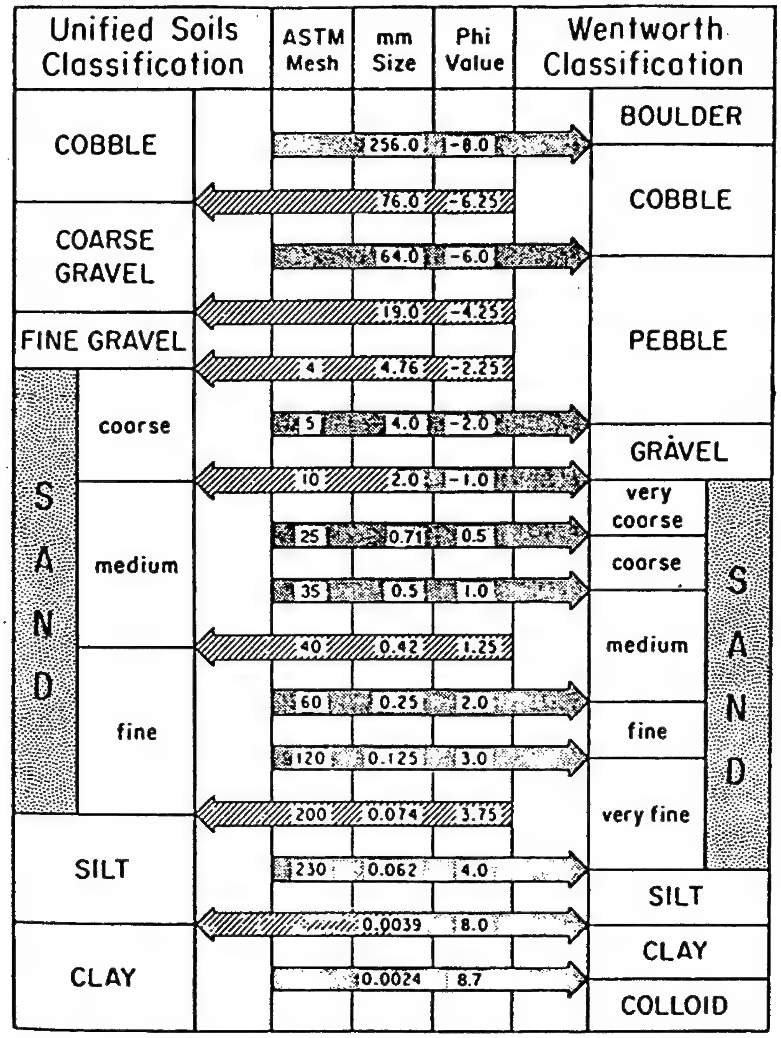


Figure 13. Grain-size scales for soil classification (Shore Protection Manual, 1984)

Discussion of Results

Equilibrium Beach Profile

The equilibrium beach profiles measured in this project seem to be very accurate representations of the sea floor variation on Mustang Island at the time of the survey. In Figure 14, the measured profiles A and B are compared. Although profile B was measured about 300 ft south of profile A, there is remarkable resemblance between the two profiles. There are no obvious differences between the two profiles, therefore it can be assumed that profile A is representative of the beach profile at the survey site. Profile A will be used throughout the remainder of this report for the analysis of sediments, beach slopes, and profile prediction methods.

In order to obtain both beach profiles, the data given by the electronic total station had to be converted from horizontal distance measurements, and horizontal and vertical angles into X, Y, and Z coordinates of position. This was accomplished through the use of a spreadsheet program. A copy of the spreadsheet for profile A and B can be found in appendices B-1 and B-2, respectively. The conversion from distance and angle measurements to X, Y, Z coordinates was completed using basic trigonometric functions. The following relationships were used in those calculations:

$$X_{coordinate} = X_{initial} - H[\cos(\theta_{horizontal})] \qquad \text{(Eq. 14)}$$

where $X_{initial}$ is an initial X value such as distance from benchmark, H is the horizontal distance measurement given by the electronic total station, and $\theta_{horizontal}$ is the horizontal

angle given by the total station.

$$Y_{coordinate} = Y_{initial} - H[\sin(\theta_{horizontal})] \quad \text{(Eq. 15)}$$

where $Y_{initial}$ is an initial Y value, and H and $\theta_{horizontal}$ are as defined above.

$$Z_{coordinate} = Z_{initial} + HI + H[\sin(\theta_{vertical})] - RH \quad \text{(Eq.16)}$$

where $Z_{initial}$ is an initial Z value, HI is the height of the electronic total station, RH is the height of the survey rod or sled, and $\theta_{vertical}$ is the vertical angle measurement given by the total station.

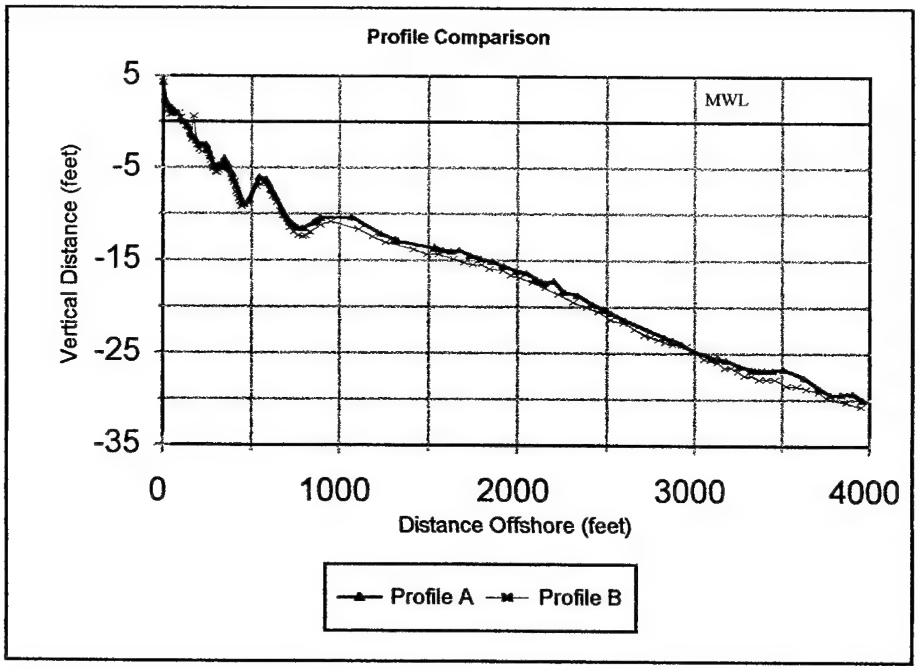


Figure 14. Measured beach profile comparison.

The matching of the land survey and offshore survey was also successful. There are no discontinuities or discrepancies between the survey conducted with the rod and the survey conducted with the sled. Both methods also seem to be very proficient at measuring irregularities in the bottom contour. Three or four distinct bars are apparent on the plot of the beach profiles in Figure 14.

There were a few sources of error in the measurement and analysis of the beach profiles. The location of the mean water line was not accurately measured in the field. All predicted profiles begin at the location of the mean water line, so an estimated mean water line was established. This was done by estimating the width of the beach from photographs, and also from notes taken by the data recorder on the location of the maximum wave runup.

Another source of error in the measurement of the actual beach profile was caused by the boat captains inability to keep the sled on the profile track. Figure 15 shows the actual sled's track along the profile lines. As seen in the figure, the sled was usually within 100 ft or 2.5 percent of the profile length off the profile line. The sled began profile B offshore at the maximum distance of 200 ft or 5 percent of the profile length off the profile line. Overall, the boat captain did maintain the sled position along the profile line reasonably well.

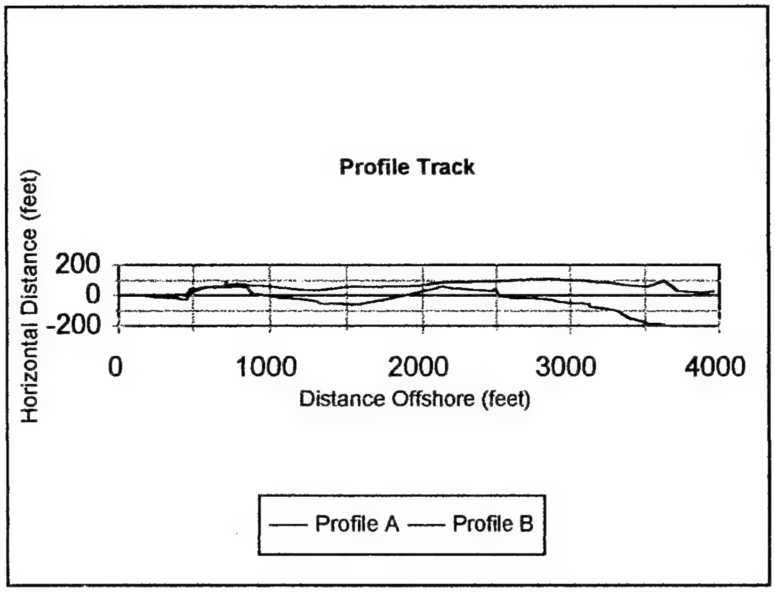


Figure 15. Actual sled track along profile line

Sediment Grain Size Analysis

The analysis of the sediment samples from profile A show the expected trend of the median grain sizes decreasing in the offshore direction. Once the sediments were sieved, the results were input into a spreadsheet program like the one seen in Table 1. With the values for number of grams retained in each sieve, the cumulative percent coarser plot for each sample was created. Figures 16-28 show the sediment distribution plots for each sample. From these plots, the values of ϕ_{16}, ϕ_{84}, and ϕ_{50}, were obtained, and the appropriate sediment characteristics were calculated. Appendix B-4 through B-6 contain the remainder of the calculations.

Table 1. Sample of sediment analysis technique.

Sample sieve #	Dune d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	3.09	0.9	0.9	99.1	0.9
80	0.180	2.47	103.08	29.9	30.8	69.2	30.8
100	0.150	2.74	94.3	27.3	58.1	41.9	58.1
120	0.125	3.00	101.75	29.5	87.6	12.4	87.6
140	0.106	3.24	34.49	10.0	97.6	2.4	97.6
170	0.090	3.47	7.23	2.1	99.7	0.3	99.7
200	0.075	3.74	1.06	0.3	100.0	0.0	100.0
		Total	345.0				
Phi 16 =	2.24			Std Dev =	0.37		
Phi 50 =	2.65			Skew =	-0.08		
Phi 84 =	2.97			Vf (cm/s)=	1.86		
d50 (mm)=	0.159			A (m^1/3)=	0.09		
M phi =	2.62			Vf (ft/s) =	0.061		
dM (mm)=	0.163			A (ft^1/3) =	0.131		

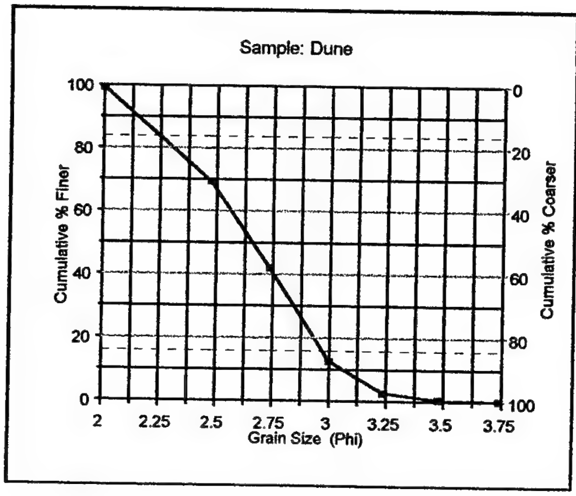


Figure 16. Sediment Distribution: Sample Dune

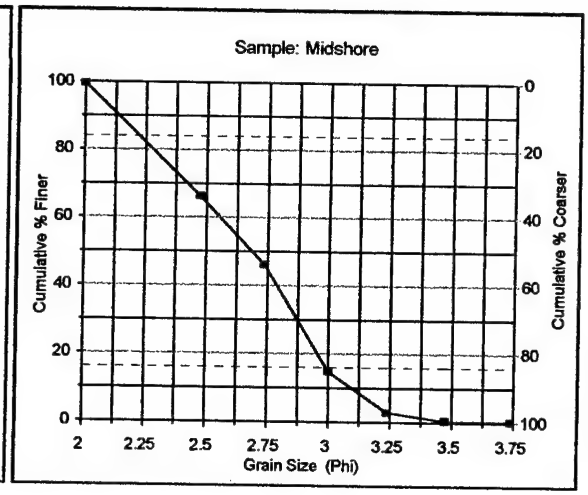


Figure 17. Sediment Distribution: Sample Midshore

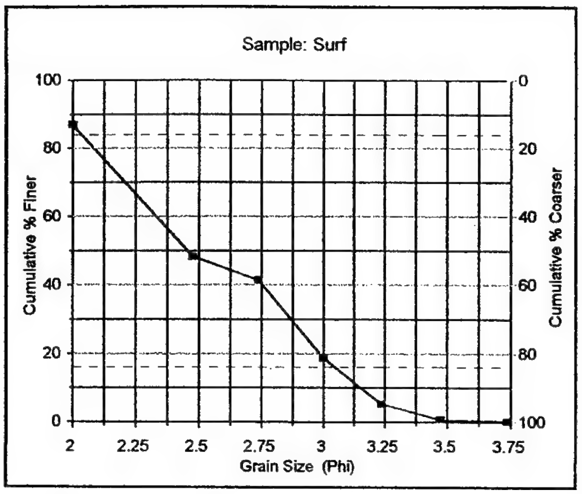


Figure 18. Sediment Distribution: Sample Surf Zone

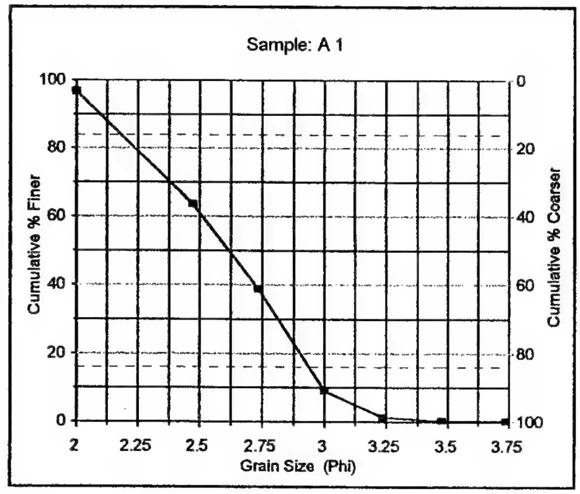


Figure 19. Sediment Distribution: Sample A-1

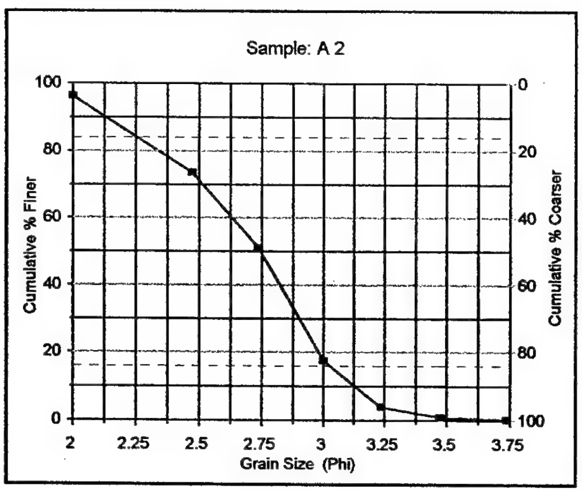


Figure 20. Sediment Distribution: Sample A-2

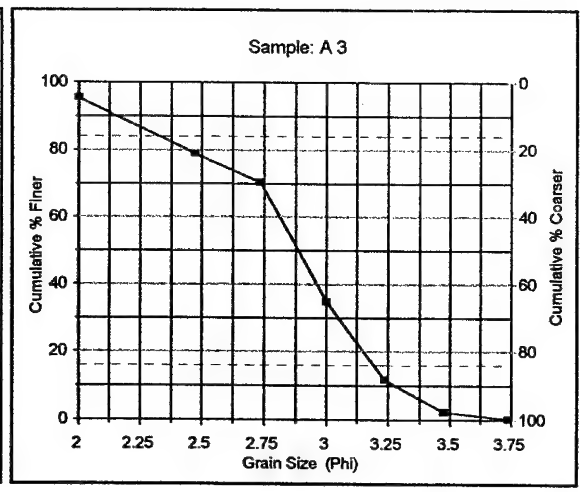


Figure 21. Sediment Distribution: Sample A-3

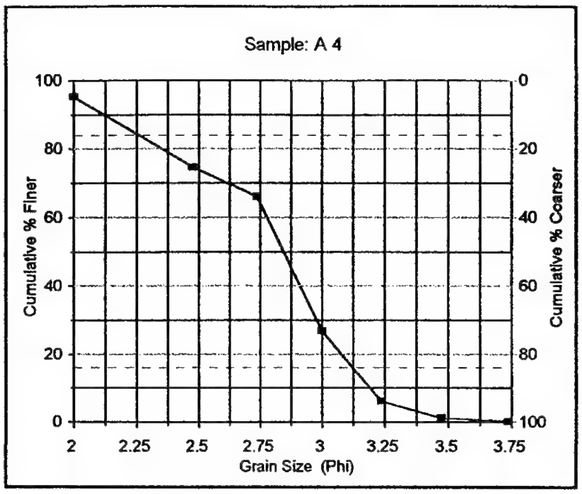


Figure 22. Sediment Distribution: Sample A-4

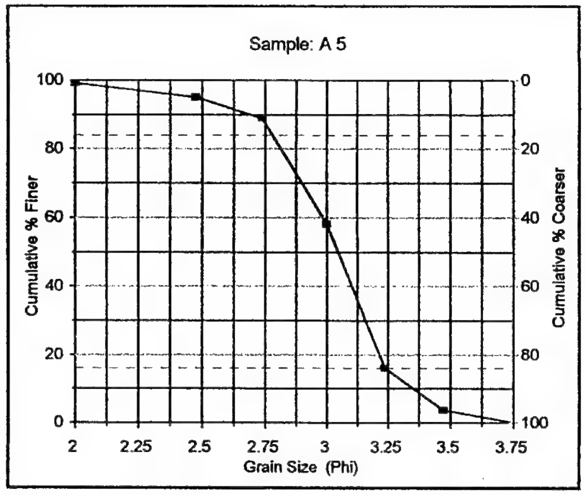


Figure 23. Sediment Distribution: Sample A-5

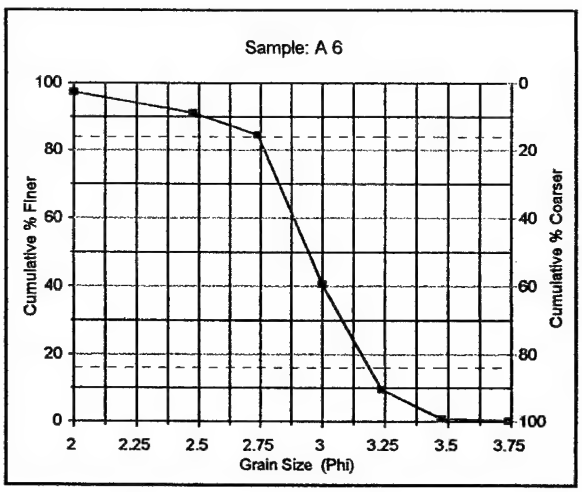


Figure 24. Sediment Distribution: Sample A-6

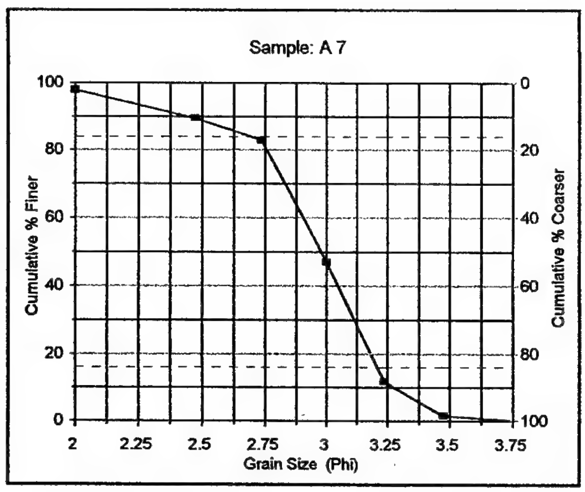
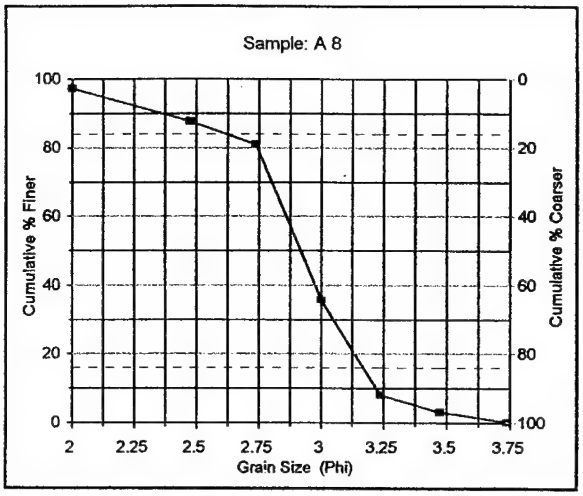


Figure 25. Sediment Distribution: Sample A-7



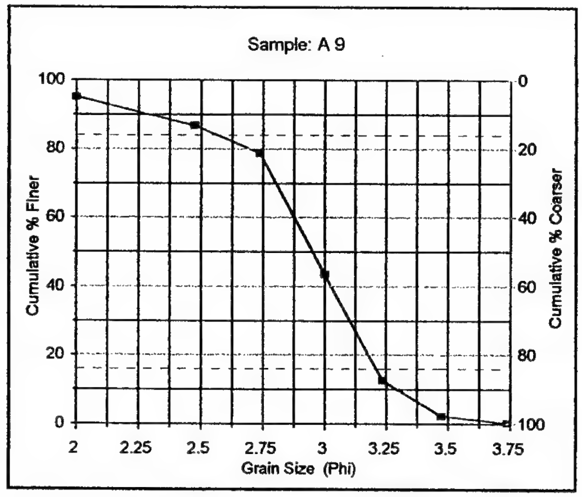


Figure 26. Sediment Distribution: Sample A-8

Figure 27. Sediment Distribution: Sample A-9

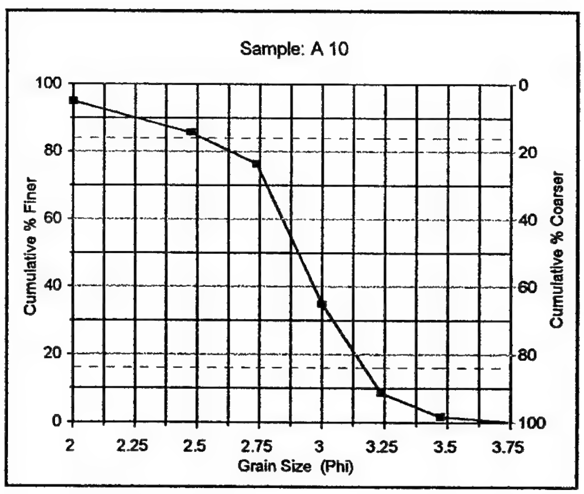


Figure 28. Sediment Distribution: Sample A-10

Table 2 summarizes the results of the sediment grain size analysis. The sediment diameters follow an obvious trend of decreasing from the surf zone offshore. This relationship has also been plotted in a method described by Bascom (1951). In an attempt to standardize his measurements and aid in the comparison of data from different beaches around the world, Bascom defined a "reference point" on the foreshore region of the beach where all other points could be referenced. For example, to show the trend in sediment grain size variation, Bascom defined a relative diameter where all the sediment samples' median grain sizes were divided by the median grain size of the reference point. Figure 30 shows this relationship for Bascom's data along the Pacific coast.

From Bascom's plot, the sediment variation in the cross-shore direction is obvious. The grain sizes reach a maximum size in the surf zone where there is maximum turbulence. From that point offshore, the sediment median grain sizes become increasingly finer. The sediment data from profile A was plotted in a similar manner in Figure 29. As expected, the same trend prevailed with the maximum grain size appearing in the surf zone and grain sizes decreasing offshore. However, the grain sizes did reach a point at about 2000 ft offshore where the median grain oscillated between 0.12 mm and 0.135 mm. The profile scale factor, A, followed the same trend as the median grain size diameters, as expected.

Table 2. Summary of sediment characteristics and beach slope.

Sample	x (ft)	d50 (mm)	% variation of d50 with reference	Vf (ft/s)	A (ft^1/3)	slope m	Std Dev	Skew
Dune	-18.8	0.159	102	0.061	0.131		0.365	-0.082
Midshore*	47.5	0.157	100	0.060	0.130	0.022	0.380	-0.123
Surf	115.0	0.183	117	0.071	0.140	0.030	0.500	0.120
1	257.6	0.163	104	0.062	0.132	0.038	0.380	-0.105
2	286.5	0.149	95	0.056	0.126	0.040	0.388	-0.194
3	404.0	0.135	86	0.051	0.121	0.030	0.430	-0.194
4	706.8	0.139	89	0.052	0.122	0.034	0.438	-0.248
5	1533.4	0.121	77	0.045	0.114	0.004	0.228	-0.139
6	2110.6	0.130	83	0.049	0.119	0.010	0.222	0.067
7	2493.8	0.127	81	0.048	0.117	0.009	0.255	-0.052
8	2876.7	0.132	84	0.050	0.119	0.009	0.273	-0.055
9	3342.1	0.129	83	0.048	0.118	0.003	0.325	-0.133
10	3959.3	0.134	86	0.050	0.120	0.008	0.325	-0.103

*indicates reference point

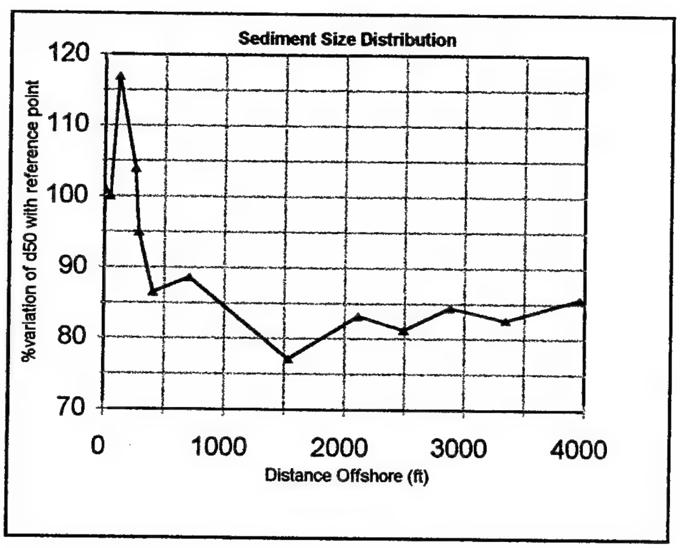


Figure 29. Distance offshore versus percent variation of d_{50} from reference diameter

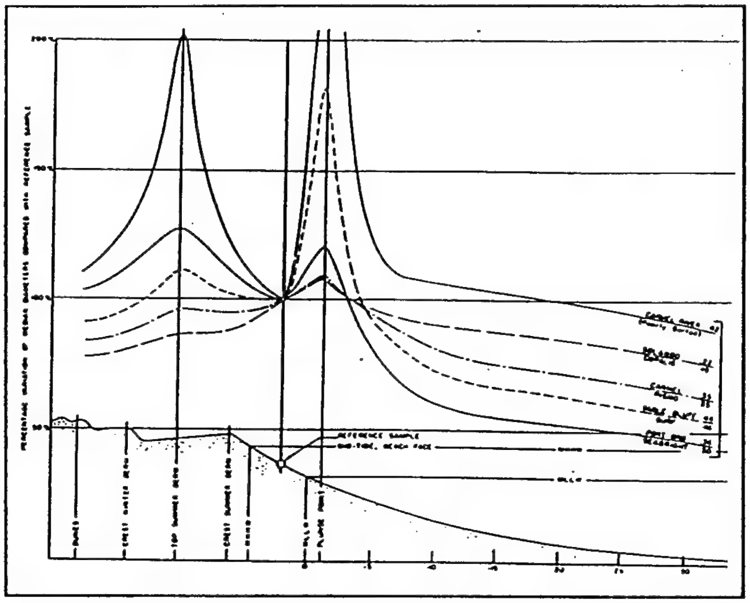


Figure 30. Distance offshore versus % Variation of d_{50} from reference diameter from Bascom (1951)

The standard deviations of the samples taken from profile A can be found in Table 2. The standard deviations of the sediments from profile A vary from about 0.22 to 0.5. These values correspond to a sample which is between perfectly sorted and well sorted. This means that the samples are poorly-graded, or their particles are close to one size.

The skewness of the samples from profile A can also be found in Table 2. Most of the samples have a negative skewness which may indicate an erosive environment. These values are very close to zero at the beginning of the profile. The skewness then seems to increase to a maximum skewness of -0.248 at about 700 ft offshore, and then the skewness decreases again. This negative skewness indicates that the sample is

skewed towards larger grain sizes, and that the finer materials have been removed from waves or currents (Dalrymple and Dean, 1996).

Beach Slope Variation

According to the Shore Protection Manual (1984), the slope of the beach depends dominantly on sediment grain size. Of course, other variables play an important role in shaping the profile of a beach such as wave energy, tides, currents and winds. The slope of Profile A changes from its steepest point in the foreshore region, to its flattest point offshore as seen in Figure 31. This change in slope also corresponds with a change in median grain size diameter along the profile. Figure 32 shows the relationship between beach slope and median grain size for Profile A.

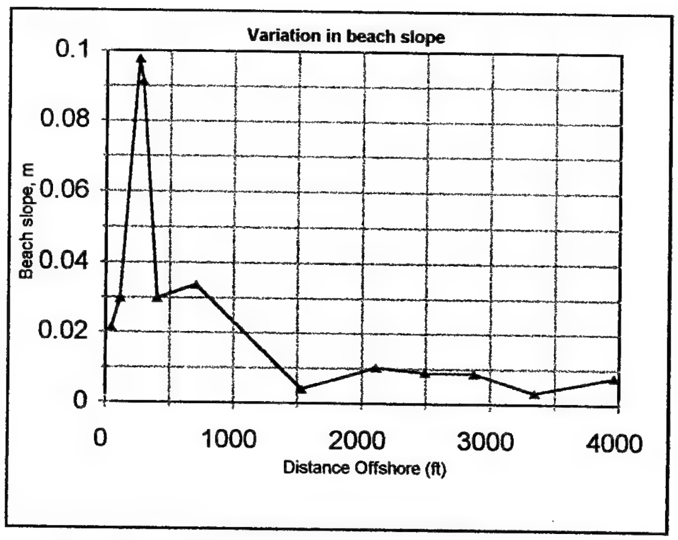


Figure 31. Variation in beach slope with distance offshore

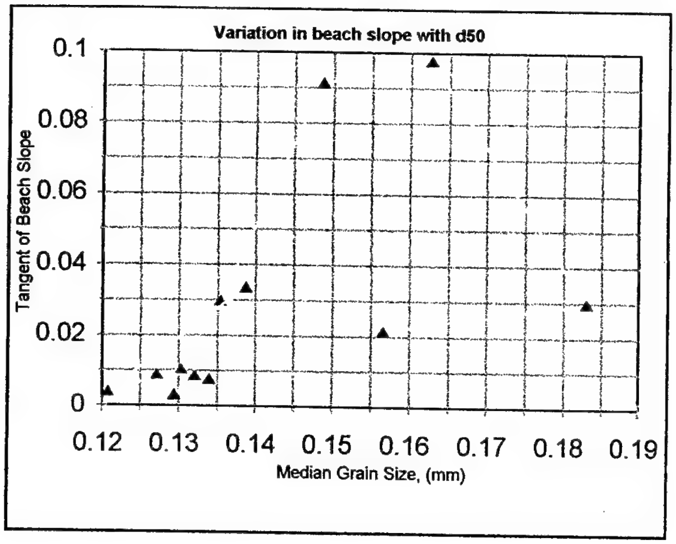


Figure 32. Variation of beach slope with median grain size

In Figure 32, the beach slope increases with an increase in median grain size. Although no definite conclusions can be drawn from this plot, a relationship is apparent

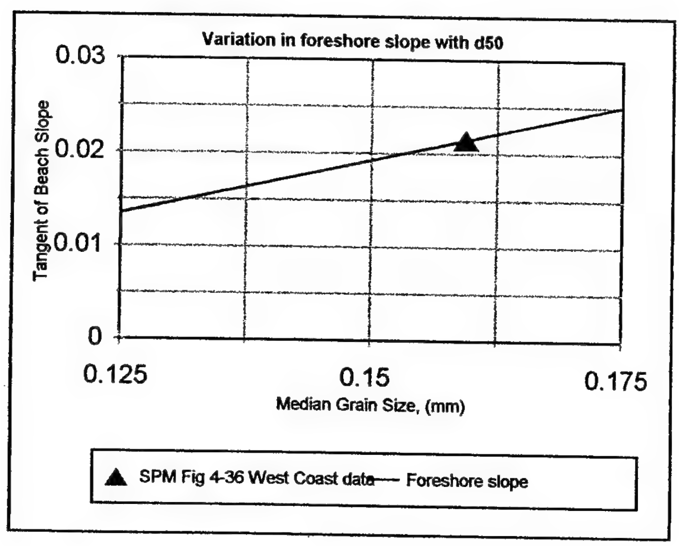


Figure 33. Median grain size versus foreshore slope comparison with SPM data

between grain size and beach slope. This figure is synonymous with Figure 34 taken from the Shore Protection Manual (1984). Figure 34 shows the relationship between foreshore slope and median grain size for beaches across the country.

In Figure 33, the foreshore slope of profile A was compared to the slope of the line in Figure 34 corresponding to the beach slopes and grain sizes of the West Coast. The West Coast data line was used in the comparison because it continued into the region of grain sizes that profile A contains. Although Figure 33 contains only one data point, and no conclusion can be drawn from this plot, it is interesting to point out that the slope of the foreshore in profile A and its corresponding grain size fall directly on the line of the West Coast data.

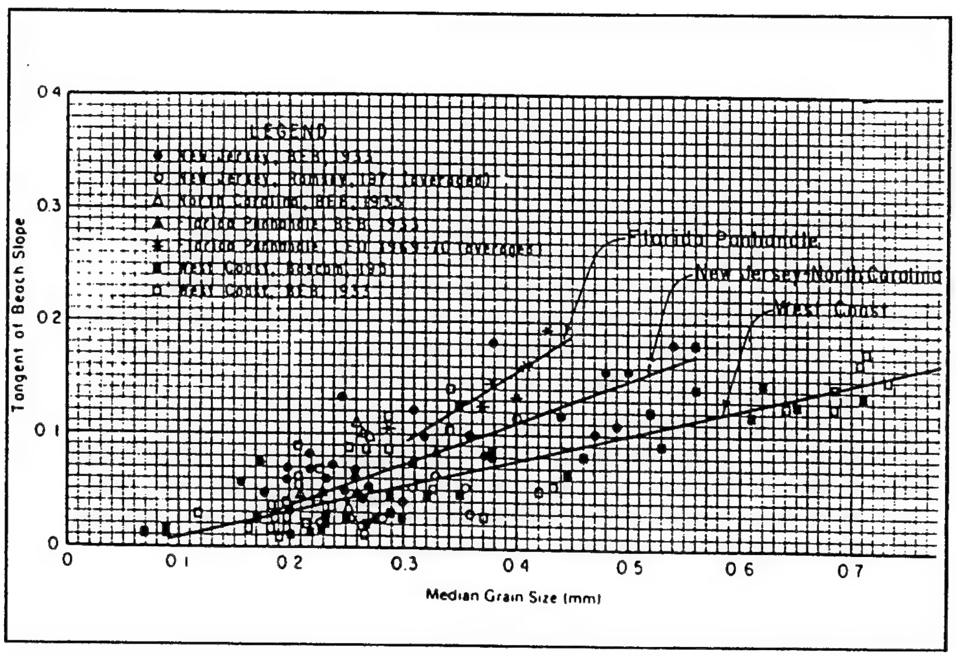


Figure 34. Median Grain size versus foreshore slope (SPM, 1984)

Equilibrium Beach Profile Prediction

As discussed before, two different methods were used to predict the equilibrium beach profile of profile A. The first method involved predicting the beach profile based on one sediment grain size obtained from the mid-shore region of the beach. The predicted profile for method 1 is based on a constant profile scale factor, A, and equation 5 was used to calculate the profile from the mean water line.

The second method accounts for variations in sediment grain size in the offshore direction. The predicted profile for method 2 is based on a profile scale factor that changes in the cross-shore direction with a change in sediment diameter. That change in profile scale factor was calculated using equation 8. The predicted profile was calculated using equation 9 from the mean water line. These calculation were completed using a spreadsheet which can be found in Appendix B-3.

Figure 35 shows a comparison of both predicted profiles against the actual profile. The results show that method 2 is a more accurate way to calculate the equilibrium beach profile. The predicted profile based on method 2 gradually changes to a flatter slope in response to the smaller median grain sizes. The predicted profile based on method 1 does not take into account this change in profile scale factor, therefore it overestimates the beach profile considerably as it moves offshore.

In order to quantify the percent error resulting from each prediction method, the area of water above each profile was calculated. This was accomplished by fitting a cubic spline through the actual profile, and both predicted profiles. With the cubic

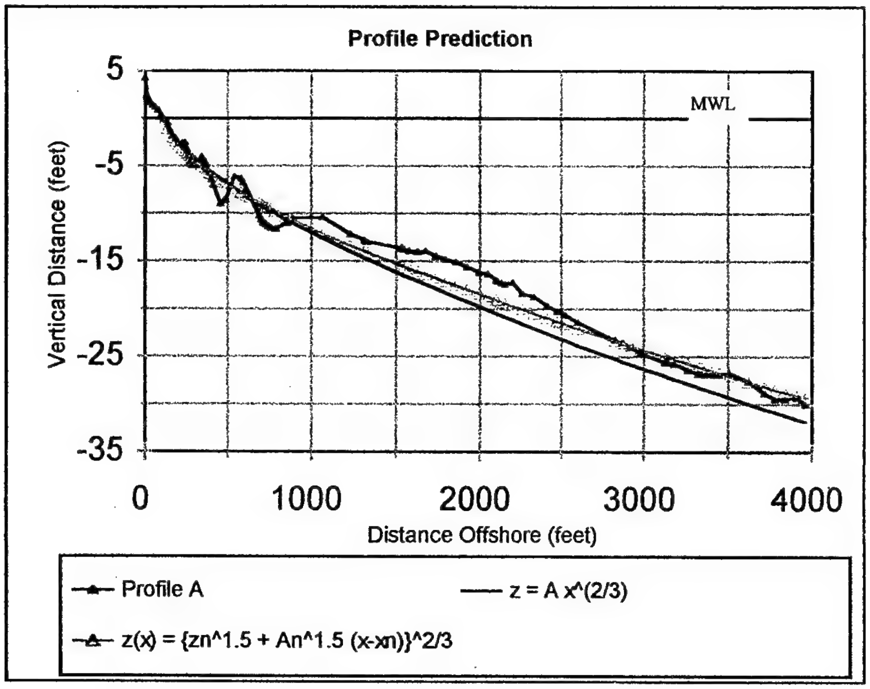


Figure 35. Predicted Profile Comparison

spline, a new set of data points representing each profile was created with equal spacing between them in the cross-shore direction. Figure 36 shows the new cubic spline line for each profile. The spacing interval was 50 ft starting at the mean water level. With equal spacing between each point, the trapezoidal rule was applied between each point in order to calculate the area in each segment. Finally, the area in all of the segments was totaled. These calculations can be found in appendices B-7 to B-9.

The percent error for each prediction method was calculated by dividing the difference in area between the actual profile and predicted profile by the area of the actual profile. The results of these calculation are shown in Table 3. As seen in the table, method 2 has considerably less error than method 1. The percent error for method

2 is 3.5%, while the error for method 1 is 10.5%. The error of method 1 is 3 times that of the error from method 2. The difference in error is equivalent to nearly 4600 cubic feet of sand per linear foot of beach. Therefore, method 2 should be the preferred method of calculating equilibrium beach profiles when the sediment data is available or when a more accurate profile prediction is required.

Table 3. Estimate of percent error for each profile prediction method.

	Profile A	Method 1: z = A x^(2/3)	Method 2: z(x) = {zn^1.5 + An^1.5 (x-xn)}^2/3
Area of water above profile (ft^2)	66,110	73,027	68,439
Difference in Area With Profile A	N/A	6,916	2,328
% difference with Profile A	N/A	10.5%	3.5%

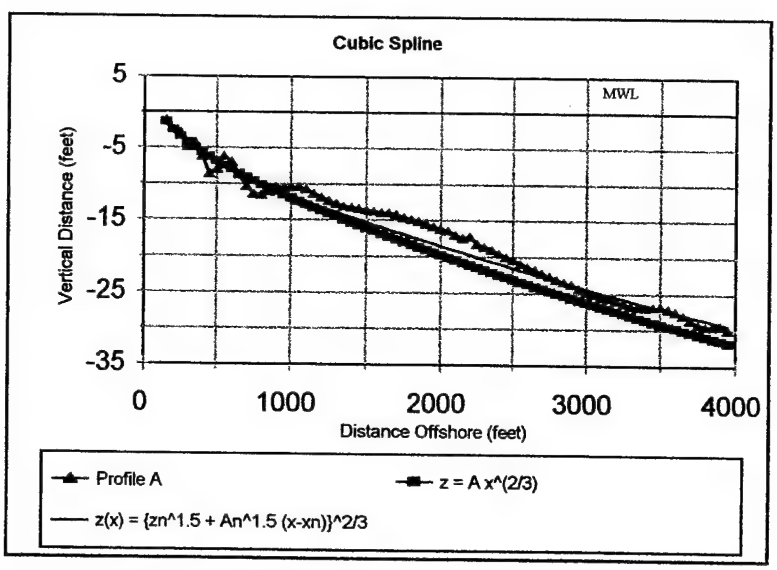


Figure 36. Cubic spline used to calculate percent error of profile predictions

Another analysis of the difference between the predicted and actual profiles was also conducted. The root mean squared distance between the actual and predicted profile was calculated using the following equation:

$$d_{rms}=((z(x)_{predicted}-z(x)_{measured})^2)^{1/2} \qquad \text{(Eq. 17)}$$

The results from this calculation showed that method 2 was still more accurate than method 1 for predicting the actual beach profile. The average root mean squared distance between the predicted and actual profiles were 2.06 and 1.10 ft for methods 1 and 2, respectively. The calculations can be found in Appendix B-10.

Conclusions and Recommendations

The main objective of this project to measure an accurate equilibrium beach profile, and compare the actual profile to a predicted profile was successfully accomplished. The actual beach profile was measured using a combination of land and offshore surveying techniques. The predicted profiles were based on two methods. One method was to simply use Dean's (1997) equation for equilibrium beach profiles, $z=Ax^{2/3}$. The other method involved a more complex analysis described by Dean and Dalrymple (1996), which accounts for a variation in sediment size and profile scale factor, A, in the offshore direction

The land survey was accomplished using an electronic total station with a standard surveying rod, and the offshore survey was completed using the Texas A & M University sea sled. The sea sled is an accurate instrument for obtaining equilibrium beach profiles from the surf zone to a depth of about 35 ft. It is durable, lightweight, easy to transport, and relatively inexpensive.

The sediment analysis for profile A showed a decrease in median grain size from the surf zone towards offshore. That decrease in median grain size corresponded to a decrease in beach slope. These results were compared to similar results from Bascom (1951). Equilibrium beach profile slope is dependent on the median grain size along the profile.

Method 2 described in this report is a much more accurate method for predicting equilibrium beach profiles than method 1. The error for method 2 was 3.5 % compared

to 10.5% for method 1. The average root mean squared distance between the actual and predicted profile for method 2 was also half that of method 1. Method 2 is a more realistic representation of predicting the equilibrium beach profile. If the sediment data is available, or a more accurate profile prediction is required, method 2 should be the method of choice.

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Birkemeier, William A., and Curtis Mason. "The CRAB: A Unique Nearshore Surveying Vehicle," Journal of Surveying Engineering, ASCE, 110, 1, 1984.

Dalrymple, Robert A., and Robert G. Dean. Coastal Processes. Unpublished, 1996.

Edge, Billy L. "Beach Nourishment Design." Texas A&M University, Class notes OCEN 672, 1997.

Shore Protection Manual. 1984. 4th ed., 2 vols., Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station, U.S. Government Printing Office, Washington, D.C.

APPENDIX

A

Erick Knezek
M.E. Project
24 SEP 97

- Talk to Dr. Robert Bruner from C.E. Dept. about borrowing survey equipment
- Chart boat: Contact James Rouso with CBI at (512) 994-5758 or (512) 815-3196. Or call Capt. John Barrera at (512) 992-8855
- Rent Trailer from Leon Sevcik's Texaco, 2200 Longmire Dr. C.S., Tx 77845 (409)-696-0065

Equipment List:

- EDM (Total Station)
- Extra Batteries
- Charger
- Survey Rod
- 4 Range Poles
- 2 Prism reflectors (triple and regular)
- Flags
- Tacks
- notebook
- Camera & Film
- Digital camera
- Diskettes
- Underwater Camera, disposable
- Video Camera & Tapes
- Hand held Radios
- Dive Gear
- Duct tape
- 100 ft measuring tape
- wooden and metal stakes
- Sledge hammer
- Sled and box with tools
- Extra Wood
- Table with chair from hydrolab
- Waterproof markers
- Zip-loc storage bags
- Water
- Ice Chests
- Tarp and tie rope
- Batteries
- Plastic Straps
- Milk Crates
- Nails

APPENDIX

B

Profile A

Point	H.I.	R.H.	H. Dist.	H.Angle				V.Angle				X	Y	Z
(#)	(feet)	(feet)	(feet)	(deg.)	(min.)	(sec.)	(dec.)	(deg.)	(min.)	(sec.)	(dec.)	(feet)	(feet)	(feet)
Pole	4.667	4.82										-18.82	0.00	**15.89**
TS 1	4.667	8.29	18.82	0	0	0	0.000	-24	-59	-30	-24.992	0.00	0.00	**4.31**
1	4.667	8.29	15.28	181	33	40	181.561	6	29	45	6.496	15.27	0.42	2.42
2	4.667	8.29	23.92	180	52	0	180.867	3	0	30	3.008	23.92	0.36	1.94
3	4.667	8.29	35.79	180	43	55	180.732	1	37	45	1.629	35.79	0.46	1.70
4	4.667	8.29	47.51	180	53	20	180.889	0	59	40	0.994	47.50	0.74	1.51
5	4.667	8.29	62.09	181	9	25	181.157	0	30	25	0.507	62.08	1.25	1.24
6	4.667	8.29	79.58	181	16	55	181.282	0	10	20	0.172	79.56	1.78	0.93
7	4.667	8.29	97.71	181	52	55	181.882	0	-10	-35	-0.176	97.66	3.21	0.39
8	4.667	8.29	115.03	180	58	20	180.972	0	-20	-30	-0.342	115.01	1.95	0.00
9	4.667	8.29	136.51	181	5	0	181.083	0	-27	-10	-0.453	136.49	2.58	-0.39
10	4.667	8.29	154.45	180	53	45	180.896	0	-44	-20	-0.739	154.43	2.41	-1.30
11	4.667	8.29	170.92	180	39	15	180.654	0	-48	-25	-0.807	170.91	1.95	-1.72
12	4.667	8.29	189.2	180	41	45	180.696	0	-49	-40	-0.828	189.19	2.30	-2.05
13	4.667	8.29	205.79	180	36	55	180.615	0	-55	-5	-0.918	205.78	2.21	-2.61
14	4.667	8.29	225.11	180	35	35	180.593	0	-49	-15	-0.821	225.10	2.33	-2.54
15	4.667	8.29	243.25	180	36	50	180.614	0	-44	-35	-0.743	243.24	2.61	-2.47
16	4.667	8.29	257.63	180	21	40	180.361	0	-52	-10	-0.869	257.62	1.62	-3.22
17	4.667	8.29	267.09	180	27	0	180.450	0	-57	-45	-0.963	267.08	2.10	-3.80
18	4.667	8.29	279.4	180	30	45	180.513	-1	-5	-15	-1.088	279.39	2.50	-4.62
19	4.667	8.29	293.27	180	23	50	180.397	-1	-6	-5	-1.101	293.26	2.03	-4.95
20	4.667	8.29	308.02	180	26	35	180.443	-1	0	-30	-1.008	308.01	2.38	-4.73
21	4.667	8.29	312.29	180	22	25	180.374	0	-59	-25	-0.990	312.28	2.04	-4.71
22	4.667	8.29	329.38	180	22	5	180.368	0	-55	-40	-0.928	329.37	2.12	-4.65
23	4.667	8.29	345.47	180	23	5	180.385	0	-46	-35	-0.776	345.46	2.32	-3.99
24	4.667	8.29	365.68	180	26	50	180.447	0	-48	-50	-0.814	365.67	2.85	-4.51
25	4.667	8.29	381.97	180	22	25	180.374	0	-54	-20	-0.906	381.96	2.49	-5.35
26	4.667	36.50	286.52	179	28	30	179.475	4	32	25	4.540	286.51	-2.63	-4.84
27	4.667	36.50	291.31	179	33	5	179.551	4	27	25	4.457	291.30	-2.28	-4.88
28	4.667	36.50	302.96	179	54	50	179.914	4	17	45	4.296	302.96	-0.46	-4.83
29	4.667	36.50	313.45	180	12	25	180.207	4	9	50	4.164	313.45	1.13	-4.76
30	4.667	36.50	315.27	180	16	15	180.271	4	8	35	4.143	315.27	1.49	-4.74
31	4.667	36.50	391.77	180	51	10	180.853	3	12	0	3.200	391.73	5.83	-5.65
32	4.667	36.50	404.09	180	55	0	180.917	2	59	45	2.996	404.04	6.46	-6.40
33	4.667	36.50	413.89	180	1	10	180.019	2	50	50	2.847	413.89	0.14	-6.96
34	4.667	36.50	458.33	181	22	35	181.376	2	19	15	2.321	458.20	11.01	-8.96
35	4.667	36.50	482.05	182	17	40	182.294	2	15	0	2.250	481.66	19.30	-8.60
36	4.667	36.50	488.46	182	19	55	182.332	2	13	55	2.232	488.06	19.87	-8.50
37	4.667	36.50	545.87	184	15	50	184.264	2	15	5	2.251	544.36	40.59	-6.08
38	4.667	36.50	584.47	185	19	55	185.332	2	4	55	2.082	581.94	54.31	-6.29
39	4.667	36.50	587.07	185	23	50	185.397	2	4	0	2.067	584.47	55.22	-6.35
40	4.667	36.50	597.57	185	26	0	185.433	1	59	55	1.999	594.89	56.58	-6.68
41	4.667	36.50	617.77	185	14	0	185.233	1	52	0	1.867	615.19	56.35	-7.40
42	4.667	36.50	640.56	184	59	0	184.983	1	43	25	1.724	638.14	55.64	-8.25
43	4.667	36.50	695.26	184	23	25	184.390	1	25	45	1.429	693.22	53.22	-10.18
44	4.667	36.50	708.77	184	14	55	184.249	1	22	20	1.372	706.82	52.51	-10.55
45	4.667	36.50	712.16	184	12	10	184.203	1	21	35	1.360	710.24	52.19	-10.62
46	4.667	36.50	722.44	187	4	20	187.072	1	19	5	1.318	716.94	88.95	-10.90
47	4.667	36.50	730.63	184	4	55	184.082	1	17	30	1.292	728.78	52.01	-11.05
48	4.667	36.50	734.73	184	4	10	184.069	1	16	55	1.282	732.88	52.14	-11.08
49	4.667	36.50	749.38	184	6	10	184.103	1	14	20	1.239	747.46	53.61	-11.32
50	4.667	36.50	767.44	184	13	5	184.218	1	11	55	1.199	765.36	56.45	-11.47
51	4.667	36.50	792.49	184	16	45	184.279	1	9	5	1.151	790.28	59.13	-11.60
52	4.667	36.50	855.9	183	24	55	183.415	1	6	20	1.106	854.38	50.99	-11.01
53	4.667	36.50	864.5	184	22	5	184.368	1	6	10	1.103	861.99	65.84	-10.88
54	4.667	36.50	876.78	184	16	50	184.281	1	5	55	1.099	874.33	65.44	-10.71
55	4.667	36.50	894.52	184	9	15	184.154	1	5	30	1.092	892.17	64.80	-10.48
56	4.667	36.50	1071.4	182	47	55	182.799	0	54	55	0.915	1070.12	52.31	-10.41
57	4.667	36.50	1232.43	181	32	50	181.547	0	42	50	0.714	1231.98	33.28	-12.17
58	4.667	36.50	1312.59	181	28	40	181.478	0	38	35	0.643	1312.15	33.85	-12.79
59	4.667	36.50	1329.4	181	25	35	181.426	0	37	40	0.628	1328.99	33.09	-12.96
60	4.667	36.50	1534.49	182	8	15	182.138	0	31	0	0.517	1533.42	57.23	-13.68
61	4.667	36.50	1535.14	182	7	40	182.128	0	31	15	0.521	1534.08	57.00	-13.57
62	4.667	36.50	1548.64	182	10	50	182.181	0	30	35	0.510	1547.52	58.92	-13.74
63	4.667	36.50	1581.63	182	7	20	182.122	0	29	35	0.493	1580.55	58.57	-13.91
64	4.667	36.50	1629.56	181	59	5	181.985	0	28	30	0.475	1628.58	56.44	-14.01
65	4.667	36.50	1676.34	181	56	15	181.938	0	27	50	0.464	1675.38	56.68	-13.95
66	4.667	36.50	1736.09	181	53	50	181.897	0	25	50	0.431	1735.14	57.48	-14.48
67	4.667	36.50	1794.67	181	51	20	181.856	0	24	20	0.406	1793.73	58.11	-14.82
68	4.667	36.50	1857.82	181	51	25	181.857	0	22	55	0.382	1856.84	60.20	-15.14
69	4.667	36.50	1923.33	181	52	35	181.876	0	21	20	0.356	1922.30	62.98	-15.59
70	4.667	36.50	1997.22	181	56	40	181.944	0	19	35	0.326	1996.07	67.77	-16.14
71	4.667	36.50	2049.65	182	2	40	182.044	0	18	45	0.313	2048.35	73.12	-16.34
72	4.667	36.50	2100.36	182	8	30	182.142	0	17	15	0.288	2098.89	78.49	-16.98
73	4.667	36.50	2112.12	182	9	55	182.165	0	16	55	0.282	2110.61	79.80	-17.13
74	4.667	36.50	2134.77	182	13	20	182.222	0	16	30	0.275	2133.16	82.78	-17.27
75	4.667	36.50	2156.45	182	14	50	182.247	0	16	5	0.268	2154.79	84.56	-17.43
76	4.667	36.50	2203.16	182	15	40	182.261	0	16	5	0.268	2201.44	86.92	-17.21
77	4.667	36.50	2263.34	182	15	55	182.265	0	13	50	0.231	2261.57	89.46	-18.41
78	4.667	36.50	2335.7	182	14	55	182.249	0	12	55	0.215	2333.90	91.64	-18.75
79	4.667	36.50	2420.08	182	11	0	182.183	0	11	5	0.185	2418.32	92.20	-19.72
80	4.667	36.50	2478.38	182	7	40	182.128	0	10	5	0.168	2476.67	92.02	-20.25
81	4.667	36.50	2495.51	182	6	20	182.106	0	9	55	0.165	2493.83	91.69	-20.32
82	4.667	36.50	2527.33	182	7	35	182.126	0	9	20	0.156	2525.59	93.77	-20.66
83	4.667	36.50	2607.27	182	8	30	182.142	0	8	5	0.135	2605.45	97.43	-21.39
84	4.667	36.50	2830.99	182	10	10	182.169	0	5	10	0.086	2828.96	107.17	-23.27
85	4.667	36.50	2878.68	182	8	25	182.140	0	4	45	0.079	2876.67	107.51	-23.54
86	4.667	36.50	2928.46	182	4	25	182.074	0	4	10	0.069	2926.54	105.96	-23.97
87	4.667	36.50	2988.8	181	59	15	181.988	0	3	15	0.054	2987.00	103.68	-24.70
88	4.667	36.50	3130.98	181	43	55	181.732	0	2	5	0.035	3129.55	94.63	-25.62
89	4.667	36.50	3131.32	181	43	55	181.732	0	2	15	0.038	3129.89	94.64	-25.47
90	4.667	36.50	3141.43	181	42	0	181.700	0	2	5	0.035	3140.05	93.19	-25.62
91	4.667	36.50	3180.56	181	36	35	181.610	0	1	55	0.032	3179.30	89.35	-25.75
92	4.667	36.50	3259.87	181	26	25	181.440	0	1	10	0.019	3258.84	81.94	-26.41
93	4.667	36.50	3326.44	181	17	30	181.292	0	0	45	0.013	3325.59	74.98	-26.80
94	4.667	36.50	3342.9	181	16	0	181.267	0	0	45	0.013	3342.08	73.90	-26.79
95	4.667	36.50	3369.01	181	13	0	181.217	0	0	40	0.011	3368.25	71.54	-26.87
96	4.667	36.50	3397.21	181	8	55	181.149	0	0	40	0.011	3396.53	68.10	-26.86
97	4.667	36.50	3446.06	181	1	55	181.032	0	0	40	0.011	3445.50	62.06	-26.85
98	4.667	36.50	3509.67	180	53	0	180.883	0	0	45	0.013	3509.25	54.11	-26.76
99	4.667	36.50	3626.92	180	89	0	181.483	0	0	-5	-0.001	3625.70	93.89	-27.61
100	4.667	36.50	3720.41	180	29	20	180.489	0	-1	-15	-0.021	3720.27	31.74	-28.87
101	4.667	36.50	3779.41	180	24	20	180.406	0	-1	-45	-0.029	3779.32	26.75	-29.44
102	4.667	36.50	3838.37	180	19	30	180.325	0	-1	-45	-0.029	3838.31	21.77	-29.47
103	4.667	36.50	3905.96	180	16	50	180.281	0	-1	-35	-0.026	3905.91	19.13	-29.32
104	4.667	36.50	3959.39	180	21	55	180.365	0	-2	-10	-0.036	3959.31	25.24	-30.02

Profile B

Point	H.I.	R.H.	H. Dist.	H.Angle				V.Angle				X	Y	Z
(#)	(feet)	(feet)	(feet)	(deg.)	(min.)	(sec.)	(dec.)	(deg.)	(min.)	(sec.)	(dec.)	(feet)	(feet)	(feet)
Pole	4.67	4.82										-18.82	300.96	20.[illegible]1
TS 1	4.67	8.29	18.82	0	0	0	0.000	-24	-59	-30	-24.992	0.00	300.96	4.31
1	4.67	8.29	25.42	177	26	0	177.433	0	51	55	0.865	25.39	299.82	1.07
2	4.67	8.29	38.02	178	28	25	178.474	0	4	50	0.081	38.01	299.95	0.74
3	4.67	8.29	50.13	179	5	30	179.092	0	5	45	0.096	50.12	300.17	0.77
4	4.67	8.29	60.62	179	11	49	179.197	0	10	40	0.178	60.61	300.11	0.88
5	4.67	8.29	74.33	178	26	10	178.436	0	10	55	0.182	74.30	298.93	0.92
6	4.67	8.29	88.5	178	38	35	178.643	0	8	20	0.139	88.48	298.86	0.90
7	4.67	8.29	101.8	178	43	0	178.717	0	-8	-25	-0.140	101.77	298.68	0.44
8	4.67	8.29	113.07	178	59	50	178.997	0	-22	-15	-0.371	113.05	298.98	-0.04
9	4.67	8.29	125.37	178	57	55	178.965	0	-32	-45	-0.546	125.35	298.70	-0.51
10	4.67	8.29	136.17	178	38	10	178.636	0	-34	-45	-0.579	136.13	297.72	-0.69
11	4.67	8.29	146.26	179	14	40	179.244	0	-43	-25	-0.724	146.25	299.03	-1.16
12	4.67	8.29	157.28	179	1	30	179.025	0	-59	-15	-0.988	157.26	298.28	-2.02
13	4.67	8.29	173.61	178	51	20	178.856	0	-3	0	-0.050	173.58	297.49	0.54
14	4.67	8.29	188.48	178	45	55	178.765	-1	0	-15	-1.004	188.44	296.90	-2.62
15	4.67	8.29	202.79	178	28	55	178.482	-1	-3	-25	-1.057	202.72	295.59	-3.05
16	4.67	8.29	220.08	178	9	20	178.156	-1	-2	-5	-1.035	219.97	293.88	-3.29
17	4.67	8.29	239.64	177	41	30	177.692	0	-55	-10	-0.919	239.45	291.31	-3.16
18	4.67	8.29	257.01	177	13	25	177.224	0	-57	-5	-0.951	256.71	288.51	-3.58
19	4.67	8.29	268.73	177	53	45	177.896	-1	-3	-20	-1.056	268.55	291.09	-4.26
20	4.67	8.29	282.34	178	6	15	178.104	-1	-10	-30	-1.175	282.19	291.62	-5.10
21	4.67	8.29	292.61	178	38	55	178.649	-1	-12	-50	-1.214	292.53	294.06	-5.51
22	4.67	8.29	302.66	179	30	55	179.515	-1	-11	-25	-1.190	302.65	298.40	-5.60
23	4.67	8.29	314.98	179	49	35	179.826	-1	-6	-5	-1.101	314.98	300.01	-5.37
24	4.67	8.29	330.25	179	47	10	179.786	-1	0	-25	-1.007	330.25	299.73	-5.12
25	4.67	8.29	353.34	179	36	50	179.614	0	-51	-40	-0.861	353.33	298.58	-4.62
26	4.67	8.29	372.73	179	30	10	179.503	0	-54	-20	-0.906	372.72	297.73	-5.20
27	4.67	8.29	391.27	179	9	40	179.161	-1	0	-20	-1.006	391.23	295.23	-6.18
28	4.67	8.29	398.9	178	51	10	178.853	-1	-3	-20	-1.056	398.82	292.97	-6.66
29	4.67	8.29	391.72	178	9	30	178.158	-1	-1	-10	-1.019	391.52	288.37	-6.28
30	4.67	8.29	401.4	178	37	15	178.621	-1	-1	-45	-1.029	401.28	291.30	-6.52
31	4.67	8.29	415.29	177	55	25	177.924	-1	-9	0	-1.150	415.02	285.91	-7.65
32	4.67	8.29	420.08	177	52	5	177.868	-1	-10	-15	-1.171	419.79	285.33	-7.90
33	4.67	8.29	429.91	177	38	30	177.642	-1	-12	-45	-1.213	429.55	283.27	-8.41
34	4.67	8.29	435.59	176	59	20	176.989	-1	-14	-10	-1.236	434.99	278.08	-8.71
35	4.67	8.29	445.48	176	35	45	176.596	-1	-16	-45	-1.279	444.69	274.51	-9.26
36	4.67	36.50	488.34	185	3	10	185.053	2	11	5	2.185	486.44	343.97	-8.90
37	4.67	36.50	537.5	184	58	10	184.969	2	10	30	2.175	535.48	347.52	-7.12
38	4.67	36.50	554.75	184	59	30	184.992	2	8	40	2.144	552.65	349.23	-6.76
39	4.67	36.50	571.97	184	59	40	184.994	2	5	0	2.083	569.80	350.76	-6.73
40	4.67	36.50	606.27	184	59	55	184.999	1	53	25	1.890	603.96	353.79	-7.52
41	4.67	36.50	622.43	184	59	35	184.993	1	47	0	1.783	620.07	355.13	-8.15
42	4.67	36.50	643.77	185	0	25	185.007	1	39	55	1.665	641.31	357.15	-8.81
43	4.67	36.50	665.63	185	1	15	185.021	1	31	55	1.532	663.08	359.21	-9.73
44	4.67	36.50	678.65	185	2	55	185.049	1	27	35	1.460	676.02	360.68	-10.23
45	4.67	36.50	720.42	185	4	5	185.068	1	16	20	1.272	717.60	364.60	-11.53
46	4.67	36.50	744.15	185	4	0	185.067	1	11	50	1.197	741.24	366.68	-11.97
47	4.67	36.50	767.7	185	3	55	185.065	1	7	50	1.131	764.70	368.74	-12.37
48	4.67	36.50	796.75	185	3	25	185.057	1	4	55	1.082	793.65	371.19	-12.48
49	4.67	36.50	813.1	185	3	25	185.057	1	3	50	1.064	809.94	372.63	-12.42
50	4.67	36.50	835.09	185	2	40	185.044	1	3	40	1.061	831.86	374.39	-12.06
51	4.67	36.50	840.87	185	2	35	185.043	1	3	45	1.063	837.61	374.88	-11.93
52	4.67	36.50	899.58	184	56	15	184.938	1	2	10	1.036	896.24	378.39	-11.25
53	4.67	36.50	954.59	184	12	55	184.215	1	0	5	1.001	952.01	371.13	-10.84
54	4.67	36.50	1109.55	182	15	45	182.263	0	49	5	0.818	1108.69	344.76	-11.68
55	4.67	36.50	1185.8	181	28	40	181.478	0	43	30	0.725	1185.41	331.54	-12.52
56	4.67	36.50	1258.9	180	35	45	180.596	0	39	25	0.657	1258.83	314.05	-13.09
57	4.67	36.50	1415.67	179	24	0	179.400	0	33	15	0.554	1415.59	286.14	-13.83
58	4.67	36.50	1489.87	178	54	20	178.906	0	30	20	0.506	1489.60	272.50	-14.38
59	4.67	36.50	1557.58	178	35	0	178.583	0	29	0	0.483	1557.10	262.45	-14.38
60	4.67	36.50	1642.15	178	11	10	178.186	0	26	30	0.442	1641.33	248.98	-14.86
61	4.67	36.50	1700.31	177	59	30	177.992	0	24	50	0.414	1699.27	241.37	-15.24
62	4.67	36.50	1750.93	177	59	35	177.993	0	23	35	0.393	1749.86	239.64	-15.51
63	4.67	36.50	1799.82	178	4	25	178.074	0	23	0	0.383	1798.80	240.46	-15.48
64	4.67	36.50	1843.98	178	13	0	178.217	0	21	40	0.361	1843.09	243.58	-15.90
65	4.67	36.50	1919.18	178	33	15	178.554	0	20	30	0.342	1918.57	252.54	-16.08
66	4.67	36.50	1961.13	178	48	15	178.804	0	19	5	0.318	1960.70	260.03	-16.63
67	4.67	36.50	2015.95	179	7	25	179.124	0	18	10	0.303	2015.71	270.13	-16.87
68	4.67	36.50	2085.91	179	30	55	179.515	0	16	40	0.278	2085.84	283.31	-17.41
69	4.67	36.50	2153.48	179	52	20	179.872	0	15	15	0.254	2153.47	296.16	-17.97
70	4.67	36.50	2227.82	180	15	55	180.265	0	13	40	0.228	2227.80	311.27	-18.66
71	4.67	36.50	2313.41	180	39	50	180.664	0	11	55	0.199	2313.25	327.76	-19.50
72	4.67	36.50	2386.43	180	55	40	180.928	0	10	45	0.179	2386.12	339.60	-20.06
73	4.67	36.50	2453.22	181	7	30	181.125	0	9	45	0.163	2452.75	349.13	-20.56
74	4.67	36.50	2524.57	181	15	0	181.250	0	8	20	0.139	2523.97	356.03	-21.40
75	4.67	36.50	2595.84	181	15	45	181.263	0	7	40	0.128	2595.21	358.15	-21.73
76	4.67	36.50	2658.64	181	9	45	181.163	0	6	35	0.110	2658.09	354.90	-22.43
77	4.67	36.50	2714.51	181	2	0	181.033	0	5	40	0.094	2714.07	349.91	-23.05
78	4.67	36.50	2750.61	180	55	45	180.929	0	5	20	0.089	2750.25	345.56	-23.25
79	4.67	36.50	2794.58	180	47	50	180.797	0	4	55	0.082	2794.31	339.84	-23.52
80	4.67	36.50	2832.31	180	39	45	180.663	0	4	30	0.075	2832.12	333.71	-23.81
81	4.67	36.50	2875.15	180	32	0	180.533	0	4	10	0.069	2875.03	327.72	-24.04
82	4.67	36.50	2953.19	180	53	25	180.890	0	3	50	0.064	2952.83	346.85	-24.23
83	4.67	36.50	3052.05	179	54	20	179.906	0	2	5	0.035	3052.05	295.93	-25.67
84	4.67	36.50	3092.57	179	44	55	179.749	0	1	55	0.032	3092.54	287.39	-25.80
85	4.67	36.50	3129.82	179	36	30	179.608	0	1	40	0.028	3129.75	279.57	-26.00
86	4.67	36.50	3170.36	179	26	50	179.447	0	1	0	0.017	3170.21	270.37	-26.60
87	4.67	36.50	3207.49	179	18	25	179.307	0	1	0	0.017	3207.26	262.16	-26.59
88	4.67	36.50	3244.65	179	10	40	179.178	0	0	35	0.010	3244.32	254.40	-26.97
89	4.67	36.50	3285.27	179	2	40	179.044	0	0	5	0.001	3284.81	246.17	-27.44
90	4.67	36.50	3325.78	178	54	30	178.908	0	0	5	0.001	3325.18	237.60	-27.44
91	4.67	36.50	3369.85	178	46	0	178.767	0	0	-20	-0.006	3369.07	228.43	-27.85
92	4.67	36.50	3413.67	178	37	50	178.631	0	0	-20	-0.006	3412.69	219.38	-27.85
93	4.67	36.50	3458.48	178	30	10	178.503	0	0	-20	-0.006	3457.30	210.60	-27.86
94	4.67	36.50	3525.79	178	16	40	178.278	0	-1	0	-0.017	3524.20	195.00	-28.55
95	4.67	36.50	3583.27	178	5	20	178.089	0	-1	0	-0.017	3581.28	181.46	-28.56
96	4.67	36.50	3638.75	177	55	10	177.919	0	-1	-15	-0.021	3636.35	168.86	-28.84
97	4.67	36.50	3711.48	177	41	25	177.690	0	-1	-35	-0.026	3708.46	151.38	-29.23
98	4.67	36.50	3762.07	177	33	10	177.553	0	-2	-10	-0.036	3758.64	140.32	-29.89
99	4.67	36.50	3872.81	177	18	20	177.306	0	-2	-30	-0.042	3868.53	118.90	-30.34
100	4.67	36.50	3958.38	177	13	10	177.219	0	-2	-50	-0.047	3953.72	108.94	-30.78

Predicted Profile Calculations

x (ft)	Profile A z (ft)	MWL	Z = A x^2/3 A=.130 ft^1/3	slope m	A (ft^1/3)	Eq. 4 A(y)	Eq.5 z (ft)	Sample Location (z)
-18.82	15.889			-0.395	0.131	0.131		15.89
0.00	4.312					0.130		
15.27	2.416					0.130		
23.92	1.943					0.130		
35.79	1.705					0.130		
47.50	1.512			-0.022	0.130	0.130		1.51
62.08	1.237					0.132		
79.56	0.927					0.134		
97.66	0.387					0.137		
115.01	0.001	0.00	0.00	-0.030	0.140	0.140	0.00	0.00
136.49	-0.391	0.00	-1.00			0.139	-1.08	
154.43	-1.304	0.00	-1.50			0.138	-1.61	
170.91	-1.720	0.00	-1.89			0.137	-2.03	
189.19	-2.046	0.00	-2.29			0.136	-2.44	
205.78	-2.610	0.00	-2.62			0.135	-2.78	
225.10	-2.538	0.00	-2.98			0.134	-3.15	
243.24	-2.467	0.00	-3.30			0.133	-3.48	
257.62	-3.222	0.00	-3.54	-0.038	0.132	0.132	-3.72	-3.22
267.08	-3.799	0.00	-3.69			0.130	-3.88	
279.39	-4.616	0.00	-3.89			0.128	-4.07	
293.26	-4.950	0.00	-4.11			0.125	-4.28	
308.01	-4.733	0.00	-4.33			0.122	-4.49	
312.28	-4.710	0.00	-4.39			0.121	-4.54	
329.37	-4.646	0.00	-4.64			0.118	-4.77	
345.46	-3.994	0.00	-4.87			0.115	-4.96	
365.67	-4.507	0.00	-5.15			0.111	-5.20	
381.96	-5.349	0.00	-5.37			0.108	-5.37	
286.51	-4.840	0.00	-4.00	-0.040	0.126	0.126	-4.35	-4.84
291.30	-4.883	0.00	-4.07			0.126	-4.42	
302.96	-4.827	0.00	-4.25			0.126	-4.58	
313.45	-4.762	0.00	-4.41			0.125	-4.73	
315.27	-4.744	0.00	-4.44			0.125	-4.75	
391.73	-5.652	0.00	-5.50			0.121	-5.74	
404.04	-6.402	0.00	-5.67	-0.030	0.121	0.121	-5.88	-6.40
413.89	-6.962	0.00	-5.79			0.121	-5.99	
458.20	-8.961	0.00	-6.35			0.121	-6.49	
481.66	-8.596	0.00	-6.64			0.121	-6.75	
488.06	-8.498	0.00	-6.72			0.121	-6.81	
544.36	-6.077	0.00	-7.38			0.121	-7.41	
581.94	-6.288	0.00	-7.80			0.122	-7.79	
584.47	-6.350	0.00	-7.83			0.122	-7.82	
594.89	-6.681	0.00	-7.94			0.122	-7.92	
615.19	-7.398	0.00	-8.17			0.122	-8.13	
638.14	-8.254	0.00	-8.41			0.122	-8.35	
693.22	-10.180	0.00	-9.00			0.122	-8.89	
706.82	-10.548	0.00	-9.14	-0.034	0.122	0.122	-9.01	-10.55
710.24	-10.622	0.00	-9.17			0.122	-9.05	
716.94	-10.903	0.00	-9.24			0.122	-9.11	
728.78	-11.051	0.00	-9.36			0.122	-9.22	
732.88	-11.083	0.00	-9.40			0.122	-9.26	
747.46	-11.319	0.00	-9.55			0.122	-9.40	
765.36	-11.468	0.00	-9.73			0.122	-9.56	
790.28	-11.597	0.00	-9.98			0.121	-9.79	
854.38	-11.007	0.00	-10.60			0.121	-10.36	
861.99	-10.883	0.00	-10.67			0.121	-10.42	
874.33	-10.710	0.00	-10.79			0.121	-10.53	
892.17	-10.479	0.00	-10.96			0.120	-10.68	
1070.12	-10.407	0.00	-12.57			0.119	-12.15	
1231.98	-12.166	0.00	-13.95			0.117	-13.39	
1312.15	-12.790	0.00	-14.61			0.116	-13.97	
1328.99	-12.955	0.00	-14.75			0.116	-14.08	
1533.42	-13.684	0.00	-16.36	-0.004	0.114	0.114	-15.49	-13.68
1534.08	-13.566	0.00	-16.37			0.114	-15.49	
1547.52	-13.744	0.00	-16.47			0.114	-15.58	
1580.55	-13.911	0.00	-16.72			0.115	-15.80	
1628.58	-14.012	0.00	-17.09			0.115	-16.11	
1675.38	-13.949	0.00	-17.44			0.115	-16.41	
1735.14	-14.475	0.00	-17.88			0.116	-16.79	
1793.73	-14.818	0.00	-18.31			0.116	-17.17	
1856.84	-15.137	0.00	-18.76			0.117	-17.57	
1922.30	-15.586	0.00	-19.23			0.117	-17.98	
1996.07	-16.144	0.00	-19.75			0.118	-18.44	
2048.35	-16.342	0.00	-20.11			0.118	-18.77	
2098.89	-16.982	0.00	-20.46			0.118	-19.08	
2110.61	-17.128	0.00	-20.54	-0.010	0.119	0.119	-19.15	-17.13
2133.16	-17.275	0.00	-20.70			0.119	-19.29	
2154.79	-17.432	0.00	-20.85			0.118	-19.43	
2201.44	-17.214	0.00	-21.16			0.118	-19.71	
2261.57	-18.413	0.00	-21.57			0.118	-20.08	
2333.90	-18.745	0.00	-22.05			0.118	-20.51	
2418.32	-19.719	0.00	-22.60			0.117	-21.01	
2476.67	-20.252	0.00	-22.98			0.117	-21.35	
2493.83	-20.322	0.00	-23.10	-0.009	0.117	0.117	-21.45	-20.32
2525.59	-20.659	0.00	-23.30			0.117	-21.64	
2605.45	-21.390	0.00	-23.81			0.118	-22.09	
2828.96	-23.266	0.00	-25.22			0.119	-23.36	
2876.67	-23.543	0.00	-25.51	-0.009	0.119	0.119	-23.63	-23.54
2926.54	-23.972	0.00	-25.82			0.119	-23.91	
2987.00	-24.695	0.00	-26.19			0.119	-24.25	
3129.55	-25.624	0.00	-27.05			0.119	-25.03	
3129.89	-25.472	0.00	-27.05			0.119	-25.04	
3140.05	-25.617	0.00	-27.11			0.119	-25.09	
3179.30	-25.748	0.00	-27.34			0.119	-25.31	
3258.84	-26.415	0.00	-27.81			0.118	-25.73	
3325.59	-26.795	0.00	-28.21			0.118	-26.09	
3342.08	-26.792	0.00	-28.30	-0.003	0.118	0.118	-26.18	-26.79
3368.25	-26.868	0.00	-28.46			0.118	-26.32	
3396.53	-26.862	0.00	-28.62			0.118	-26.46	
3445.50	-26.853	0.00	-28.90			0.119	-26.72	
3509.25	-26.755	0.00	-29.27			0.119	-27.06	
3625.70	-27.609	0.00	-29.94			0.119	-27.66	
3720.27	-28.874	0.00	-30.47			0.119	-28.15	
3779.32	-29.445	0.00	-30.81			0.120	-28.46	
3838.31	-29.475	0.00	-31.13			0.120	-28.76	
3905.91	-29.320	0.00	-31.51			0.120	-29.11	
3959.31	-30.016	0.00	-31.81	-0.008	0.120	0.120	-29.39	-30.02

Summary table

Sample	x (ft)	d50 (mm)	Vf (ft/s)	A (ft^1/3)	Sample	x (ft)	d50 (mm)
Dune	-18.82	0.159	0.061	0.131	5	1533.42	0.121
Midshore	47.5043	0.157	0.060	0.130	6	2110.61	0.130
surf	115.013	0.183	0.071	0.140	7	2493.83	0.127
1	257.625	0.163	0.062	0.132	8	2876.67	0.132
2	286.508	0.149	0.056	0.126	9	3342.08	0.129
3	404.038	0.135	0.051	0.121	10	3959.31	0.134
4	706.822	0.139	0.052	0.122			

Profile A

Sample	Dune		retained	% retained		%	%
sieve #	d (mm)	Phi	(gms)	partial	total	finer	coarser
60	0.250	2.00	3.09	0.9	0.9	99.1	0.9
80	0.180	2.47	103.08	29.9	30.8	69.2	30.8
100	0.150	2.74	94.3	27.3	58.1	41.9	58.1
120	0.125	3.00	101.75	29.5	87.6	12.4	87.6
140	0.106	3.24	34.49	10.0	97.6	2.4	97.6
170	0.090	3.47	7.23	2.1	99.7	0.3	99.7
200	0.075	3.74	1.06	0.3	100.0	0.0	100.0
		Total	345.0				

Phi 16 =	2.24		Std Dev =	0.37
Phi 50 =	2.65		Skew =	-0.08
Phi 84 =	2.97		Vf (cm/s)=	1.86
d50 (mm)	0.159		A (m^1/3)=	0.09
M phi =	2.62		Vf (ft/s) =	0.061
dM (mm):	0.163	(Folk-Ward)	A (ft^1/3) =	0.131

Sample	Midshore		retained	% retained		%	%
sieve #	d (mm)	Phi	(gms)	partial	total	finer	coarser
60	0.250	2.00	2.1	0.5	0.5	99.5	0.5
80	0.180	2.47	133.5	33.3	33.9	66.1	33.9
100	0.150	2.74	80.9	20.2	54.1	45.9	54.1
120	0.125	3.00	125.4	31.3	85.4	14.6	85.4
140	0.106	3.24	47.8	11.9	97.3	2.7	97.3
170	0.090	3.47	9.7	2.4	99.7	0.3	99.7
200	0.075	3.74	1.1	0.3	100.0	-0.0	100.0
			400.5				

Phi 16 =	2.23		Std dev =	0.38
Phi 50 =	2.68		Skew =	-0.12
Phi 84 =	2.99		Vf (cm/s)=	1.82
d50 (mm)	0.157		A (m^1/3)=	0.09
M phi =	2.63		Vf (ft/s) =	0.060
dM (mm):	0.162	(Folk-Ward)	A (ft^1/3) =	0.130

Sample	surf		retained	% retained		%	%
sieve #	d (mm)	Phi	(gms)	partial	total	finer	coarser
60	0.250	2.00	52.68	13.1	13.1	86.9	13.1
80	0.180	2.47	155.43	38.7	51.9	48.1	51.9
100	0.150	2.74	27.49	6.8	58.7	41.3	58.7
120	0.125	3.00	91.65	22.8	81.5	18.5	81.5
140	0.106	3.24	53.76	13.4	94.9	5.1	94.9
170	0.090	3.47	18.01	4.5	99.4	0.6	99.4
200	0.075	3.74	2.31	0.6	100.0	-0.0	100.0
			401.3				

Phi 16 =	2.04		Std dev =	0.50
Phi 50 =	2.45		Skew =	0.12
Phi 84 =	3.04		Vf (cm/s)=	2.16
d50 (mm)	0.183		A (m^1/3)=	0.09
M phi =	2.51		Vf (ft/s) =	0.071
dM (mm):	0.176	(Folk-Ward)	A (ft^1/3) =	0.140

Sample	1		retained	% retained		%	%
sieve #	d (mm)	Phi	(gms)	partial	total	finer	coarser
60	0.250	2.00	13.21	3.3	3.3	96.7	3.3
80	0.180	2.47	134.24	33.3	36.5	63.5	36.5
100	0.150	2.74	99.77	24.7	61.3	38.7	61.3
120	0.125	3.00	120.01	29.7	91.0	9.0	91.0
140	0.106	3.24	31.61	7.8	98.9	1.1	98.9
170	0.090	3.47	3.89	1.0	99.8	0.2	99.8
200	0.075	3.74	0.71	0.2	100.0	0.0	100.0
			403.4				

Phi 16 =	2.18		Std dev =	0.38
Phi 50 =	2.62		Skew =	-0.11
Phi 84 =	2.94		Vf (cm/s)=	1.90
d50 (mm)	0.163		A (m^1/3)=	0.09
M phi =	2.58		Vf (ft/s) =	0.062
dM (mm):	0.167	(Folk-Ward)	A (ft^1/3) =	0.132

Sample 2

sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	15.61	3.9	3.9	96.1	3.9
80	0.180	2.47	91.06	22.6	26.4	73.6	26.4
100	0.150	2.74	90.72	22.5	48.9	51.1	48.9
120	0.125	3.00	135.9	33.7	82.6	17.4	82.6
140	0.106	3.24	55.09	13.7	96.3	3.7	96.3
170	0.090	3.47	12.38	3.1	99.4	0.6	99.4
200	0.075	3.74	2.57	0.6	100.0	-0.0	100.0
			403.3				

Phi 16 =	2.25	Std dev =	0.39
Phi 50 =	2.75	Skew =	-0.19
Phi 84 =	3.03	Vf (cm/s)=	1.72
d50 (mm)	0.149	A (m^1/3)=	0.09
M phi =	2.68	Vf (ft/s) =	0.056
dM (mm):	0.157 (Folk-Ward)	A (ft^1/3) =	0.126

Sample 3

sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	18.74	4.6	4.6	95.4	4.6
80	0.180	2.47	66.51	16.5	21.1	78.9	21.1
100	0.150	2.74	35.1	8.7	29.8	70.2	29.8
120	0.125	3.00	143.62	35.5	65.3	34.7	65.3
140	0.106	3.24	93.31	23.1	88.4	11.6	88.4
170	0.090	3.47	38.29	9.5	97.9	2.1	97.9
200	0.075	3.74	8.65	2.1	100.0	0.0	100.0
			404.2				

Phi 16 =	2.33	Std dev =	0.43
Phi 50 =	2.89	Skew =	-0.19
Phi 84 =	3.19	Vf (cm/s)=	1.55
d50 (mm)	0.135	A (m^1/3)=	0.08
M phi =	2.80	Vf (ft/s) =	0.051
dM (mm):	0.143 (Folk-Ward)	A (ft^1/3) =	0.121

Sample 4

sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	19.36	4.8	4.8	95.2	4.8
80	0.180	2.47	82.81	20.7	25.5	74.5	25.5
100	0.150	2.74	34.24	8.6	34.1	65.9	34.1
120	0.125	3.00	156.96	39.2	73.3	26.7	73.3
140	0.106	3.24	83.14	20.8	94.1	5.9	94.1
170	0.090	3.47	19.4	4.8	98.9	1.1	98.9
200	0.075	3.74	4.4	1.1	100.0	-0.0	100.0
			400.3				

Phi 16 =	2.25	Std dev =	0.44
Phi 50 =	2.85	Skew =	-0.25
Phi 84 =	3.13	Vf (cm/s)=	1.59
d50 (mm)	0.139	A (m^1/3)=	0.08
M phi =	2.74	Vf (ft/s) =	0.052
dM (mm):	0.150 (Folk-Ward)	A (ft^1/3) =	0.122

Sample 5

sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	4.45	1.0	1.0	99.0	1.0
80	0.180	2.47	17.05	4.0	5.0	95.0	5.0
100	0.150	2.74	25.92	6.1	11.1	88.9	11.1
120	0.125	3.00	131.91	30.9	42.0	58.0	42.0
140	0.106	3.24	179.97	42.1	84.1	15.9	84.1
170	0.090	3.47	52.9	12.4	96.5	3.5	96.5
200	0.075	3.74	15	3.5	100.0	-0.0	100.0
			427.2				

Phi 16 =	2.78	Std dev =	0.23
Phi 50 =	3.05	Skew =	-0.14
Phi 84 =	3.23	Vf (cm/s)=	1.37
d50 (mm)	0.121	A (m^1/3)=	0.08
M phi =	3.02	Vf (ft/s) =	0.045
dM (mm):	0.123 (Folk-Ward)	A (ft^1/3) =	0.114

Sample 6

sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	11.26	2.8	2.8	97.2	2.8
80	0.180	2.47	25.02	6.2	9.0	91.0	9.0
100	0.150	2.74	26.76	6.6	15.6	84.4	15.6
120	0.125	3.00	176.86	43.8	59.5	40.5	59.5
140	0.106	3.24	125.86	31.2	90.6	9.4	90.6
170	0.090	3.47	34.93	8.7	99.3	0.7	99.3
200	0.075	3.74	2.8	0.7	100.0	0.0	100.0
			403.5				

Phi 16 =	2.74	Std dev =	0.22
Phi 50 =	2.94	Skew =	0.07
Phi 84 =	3.19	Vf (cm/s)=	1.49
d50 (mm)	0.130	A (m^1/3)=	0.08
M phi =	2.96	Vf (ft/s) =	0.049
dM (mm):	0.129 (Folk-Ward)	A (ft^1/3) =	0.119

Sample 7 sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	9.12	2.2	2.2	97.8	2.2
80	0.180	2.47	34.61	8.4	10.6	89.4	10.6
100	0.150	2.74	26.86	6.5	17.2	82.8	17.2
120	0.125	3.00	147.66	35.9	53.1	46.9	53.1
140	0.106	3.24	145.15	35.3	88.4	11.6	88.4
170	0.090	3.47	41.56	10.1	98.5	1.5	98.5
200	0.075	3.74	5.96	1.5	100.0	0.0	100.0
			410.9				

Phi 16 =	2.70		Std dev =	0.25
Phi 50 =	2.98		Skew =	-0.05
Phi 84 =	3.21		Vf (cm/s)=	1.45
d50 (mm	0.127		A (m^1/3)=	0.08
M phi =	2.96		Vf (ft/s) =	0.048
dM (mm)	0.128	(Folk-Ward)	A (ft^1/3) =	0.117

Sample 8 sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	11.68	2.8	2.8	97.2	2.8
80	0.180	2.47	38.94	9.5	12.3	87.7	12.3
100	0.150	2.74	27.66	6.7	19.1	80.9	19.1
120	0.125	3.00	186.06	45.4	64.4	35.6	64.4
140	0.106	3.24	113.47	27.7	92.1	7.9	92.1
170	0.090	3.47	20.44	5.0	97.1	2.9	97.1
200	0.075	3.74	11.99	2.9	100.0	0.0	100.0
			410.2				

Phi 16 =	2.63		Std dev =	0.27
Phi 50 =	2.92		Skew =	-0.06
Phi 84 =	3.17		Vf (cm/s)=	1.51
d50 (mm	0.132		A (m^1/3)=	0.08
M phi =	2.91		Vf (ft/s) =	0.050
dM (mm)	0.134	(Folk-Ward)	A (ft^1/3) =	0.119

Sample 9 sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	19.95	5.1	5.1	94.9	5.1
80	0.180	2.47	32.55	8.3	13.3	86.7	13.3
100	0.150	2.74	31.46	8.0	21.3	78.7	21.3
120	0.125	3.00	139.37	35.4	56.7	43.3	56.7
140	0.106	3.24	121.81	30.9	87.7	12.3	87.7
170	0.090	3.47	40.34	10.2	97.9	2.1	97.9
200	0.075	3.74	8.2	2.1	100.0	-0.0	100.0
			393.7				

Phi 16 =	2.56		Std dev =	0.33
Phi 50 =	2.95		Skew =	-0.13
Phi 84 =	3.21		Vf (cm/s)=	1.48
d50 (mm	0.129		A (m^1/3)=	0.08
M phi =	2.91		Vf (ft/s) =	0.048
dM (mm)	0.133	(Folk-Ward)	A (ft^1/3) =	0.118

Sample 10 sieve #	d (mm)	Phi	retained (gms)	% retained partial	total	% finer	% coarser
60	0.250	2.00	20.89	5.2	5.2	94.8	5.2
80	0.180	2.47	37.43	9.2	14.4	85.6	14.4
100	0.150	2.74	37.63	9.3	23.7	76.3	23.7
120	0.125	3.00	168.39	41.6	65.3	34.7	65.3
140	0.106	3.24	106.39	26.3	91.5	8.5	91.5
170	0.090	3.47	28.15	7.0	98.5	1.5	98.5
200	0.075	3.74	6.09	1.5	100.0	0.0	100.0
			405.0				

Phi 16 =	2.53		Std dev =	0.33
Phi 50 =	2.90		Skew =	-0.10
Phi 84 =	3.18		Vf (cm/s)=	1.53
d50 (mm	0.134		A (m^1/3)=	0.08
M phi =	2.87		Vf (ft/s) =	0.050
dM (mm)	0.137	(Folk-Ward)	A (ft^1/3) =	0.120

Actual Profile A

x (ft)	z (ft)	coefficient	new x (ft)	new z (ft)	Area (ft^2
-18.82	15.8885	-0.6151025			
0	4.31231	-0.1241531			
15.2743	2.41596	-0.0547604			
23.9173	1.94267	-0.020036	150	-1.0789887	
35.7871	1.70484	-0.0164689	200	-2.4135635	-87.3138
47.5043	1.51187	-0.0188843	250	-2.8220377	-130.89
62.0773	1.23667	-0.0177404	300	-4.8508534	-191.822
79.5601	0.92652	-0.0298395	350	-4.1090877	-223.999
97.6573	0.38651	-0.0221903	400	-6.1558913	-256.624
115.013	0.00137	-0.0182939	450	-8.5910408	-368.673
136.486	-0.39144	-0.0508754	500	-7.9843899	-414.386
154.431	-1.30442	-0.0252092	550	-6.108694	-352.327
170.909	-1.71981	-0.0178491	600	-6.8612625	-324.249
189.186	-2.04605	-0.0339854	650	-8.6689766	-388.256
205.778	-2.60994	0.0037464	700	-10.363544	-475.813
225.098	-2.53756	0.0038762	750	-11.339799	-542.584
243.236	-2.46725	-0.0524528	800	-11.507181	-571.175
257.625	-3.22198	-0.0610433	850	-11.047242	-563.861
267.082	-3.79926	-0.0663231	900	-10.47543	-538.067
279.389	-4.61551	-0.0240967	950	-10.455185	-523.265
293.263	-4.94983	0.0146909	1000	-10.43494	-522.253
308.011	-4.73317	0.0054426	1050	-10.414696	-521.241
312.283	-4.70991	0.0037382	1100	-10.731273	-528.649
329.373	-4.64603	0.0405358	1150	-11.274693	-550.149
345.462	-3.99385	-0.0253957	1200	-11.818114	-577.32
365.669	-4.50701	-0.0517051	1250	-12.30591	-603.101
381.962	-5.34944	-0.0053357	1300	-12.694985	-625.022
286.508	-4.84013	-0.0090155	1350	-13.030234	-643.13
291.301	-4.88334	0.0047952	1400	-13.208417	-655.966
302.96	-4.82743	0.0062831	1450	-13.3866	-664.875
313.448	-4.76153	0.0097965	1500	-13.564783	-673.785
315.266	-4.74372	-0.0118769	1550	-13.756501	-683.032
391.727	-5.65183	-0.0609259	1600	-13.951484	-692.7
404.038	-6.40193	-0.0568382	1650	-13.982895	-698.359
413.89	-6.96188	-0.0451166	1700	-14.165662	-703.714
458.198	-8.9609	0.0155576	1750	-14.562063	-718.193
481.664	-8.59582	0.0153076	1800	-14.849602	-735.292
488.055	-8.49798	0.0429979	1850	-15.101984	-748.79
544.359	-6.07704	-0.0056115	1900	-15.432646	-763.366
581.941	-6.28793	-0.024536	1950	-15.795234	-780.697
584.467	-6.34991	-0.0317424	2000	-16.158693	-798.848
594.885	-6.6806	-0.0353206	2050	-16.362913	-813.04
615.195	-7.39795	-0.0373173	2100	-16.995603	-833.963
638.139	-8.25416	-0.0349725	2150	-17.397354	-859.824
693.22	-10.1805	-0.0269997	2200	-17.220444	-865.445
706.822	-10.5477	-0.0216624	2250	-18.18257	-885.075
710.245	-10.6219	-0.0419929	2300	-18.589662	-919.306
716.943	-10.9032	-0.01251	2350	-18.930751	-938.01
728.777	-11.0512	-0.0078564	2400	-19.507361	-960.953
732.878	-11.0834	-0.0161322	2450	-20.008013	-987.884
747.46	-11.3187	-0.0083175	2500	-20.387899	-1009.9
765.361	-11.4676	-0.0051774	2550	-20.882876	-1031.77
790.281	-11.5966	0.0091988	2600	-21.340553	-1055.59
854.38	-11.007	0.0163	2650	-21.764327	-1077.62
861.989	-10.8829	0.0139803	2700	-22.183953	-1098.71
874.334	-10.7103	0.0129927	2750	-22.60358	-1119.69
892.17	-10.4786	0.0004049	2800	-23.023206	-1140.67
1070.12	-10.4065	-0.0108684	2850	-23.388512	-1160.29
1231.98	-12.1657	-0.0077815	2900	-23.743762	-1178.31
1312.15	-12.7896	-0.0098486	2950	-24.25246	-1199.91
1328.99	-12.9554	-0.0035637	3000	-24.780078	-1225.81
1533.42	-13.6839	0.178228	3050	-25.105634	-1247.14
1534.08	-13.5664	-0.0132166	3100	-25.43119	-1263.42
1547.52	-13.744	-0.0050436	3150	-25.650339	-1277.04
1580.55	-13.9106	-0.0021036	3200	-25.92129	-1289.29
1628.58	-14.0116	0.0013407	3250	-26.340585	-1306.55
1675.38	-13.9489	-0.0088062	3300	-26.64938	-1324.75
1735.14	-14.4751	-0.0058516	3350	-26.814695	-1336.6
1793.73	-14.8179	-0.0050476	3400	-26.861541	-1341.91
1856.84	-15.1365	-0.0068615	3450	-26.845865	-1342.69
1922.3	-15.5856	-0.0075659	3500	-26.769465	-1340.38
1996.07	-16.1438	-0.0037909	3550	-27.05401	-1345.59
2048.35	-16.342	-0.0126586	3600	-27.420518	-1361.86
2098.89	-16.9818	-0.01244	3650	-27.933885	-1383.86
2110.61	-17.1276	-0.0065306	3700	-28.602628	-1413.41
2133.16	-17.2749	-0.0072738	3750	-29.161354	-1444.1
2154.79	-17.4322	0.0046841	3800	-29.455467	-1465.42
2201.44	-17.2137	-0.0199544	3850	-29.448158	-1472.59
2261.57	-18.4135	-0.004585	3900	-29.333552	-1469.54
2333.9	-18.7451	-0.0115322	3950	-29.895029	-1480.71
2418.32	-19.7187	-0.0091343		Total Area	-66110.4
2476.67	-20.2516	-0.0041239			
2493.83	-20.3224	-0.0106111			
2525.59	-20.6594	-0.0091535			
2605.45	-21.3904	-0.0083925			
2828.96	-23.2663	-0.0058106			
2876.67	-23.5435	-0.0085849			
2926.54	-23.9716	-0.011972			
2987	-24.6954	-0.0065111			
3129.55	-25.6236	0.4473123			
3129.89	-25.4716	-0.014342			
3140.05	-25.6173	-0.0033238			
3179.3	-25.7477	-0.0083859			
3258.84	-26.4147	-0.0057012			
3325.59	-26.7953	0.0002178			
3342.08	-26.7917	-0.0029033			
3368.25	-26.8677	0.0001934			
3396.53	-26.8622	0.0001934			
3445.5	-26.8527	0.001528			
3509.25	-26.7553	-0.0073302			
3625.7	-27.6089	-0.0133749			
3720.27	-28.8738	-0.0096738			
3779.32	-29.4449	-0.0005088			
3838.31	-29.475	0.0022921			
3905.91	-29.32	-0.0130431			
3959.31	-30.0165				

z= Ax^2/3

Method 1 Profile A Predicted

x (ft)	z (ft)	coefficien	new x (ft)	new z (ft)	Area (ft^2)
115.01344	0	-0.04663			
136.4856	-1.00126	-0.02786			
154.43112	-1.501149	-0.02389			
170.90886	-1.894729	-0.02152	150	-1.37771583	
189.18605	-2.288014	-0.01987	200	-2.50284007	-97.0139
205.77813	-2.617626	-0.0186	250	-3.40947137	-147.8078
225.09794	-2.977011	-0.01757	300	-4.20707791	-190.4137
243.23604	-3.295637	-0.01683	350	-4.93473849	-228.5454
257.62488	-3.537794	-0.01636	400	-5.61253782	-263.6819
267.08176	-3.692514	-0.01598	450	-6.24955219	-296.5523
279.38882	-3.889146	-0.01556	500	-6.85635874	-327.6478
293.26295	-4.10502	-0.01515	550	-7.43992919	-357.4072
308.01079	-4.328432	-0.0149	600	-8.00019086	-386.003
312.28336	-4.39208	-0.01464	650	-8.53966095	-413.4963
329.3732	-4.642214	-0.01426	700	-9.06540232	-440.1266
345.46221	-4.871686	-0.0139	750	-9.57491086	-466.0078
365.66886	-5.152457	-0.01356	800	-10.0700476	-491.124
381.96188	-5.373385	-0.01438	850	-10.5550045	-515.6263
286.50797	-4.000644	-0.01548	900	-11.0266102	-539.5404
291.30107	-4.074843	-0.01524	950	-11.4801908	-562.67
302.95966	-4.252576	-0.01495	1000	-11.9337713	-585.3491
313.44796	-4.409349	-0.01479	1050	-12.3873518	-608.0281
315.26648	-4.436247	-0.01396	1100	-12.8251383	-630.3123
391.72661	-5.503634	-0.01316	1150	-13.2522878	-651.9357
404.03829	-5.665694	-0.013	1200	-13.6794373	-673.2931
413.88998	-5.793721	-0.01262	1250	-14.1009673	-694.5101
458.19776	-6.353036	-0.0122	1300	-14.5125235	-715.3373
481.66353	-6.639431	-0.01204	1350	-14.9149718	-735.6874
488.05549	-6.716374	-0.01172	1400	-15.3093654	-755.6084
544.35914	-7.37623	-0.01129	1450	-15.703759	-775.3281
581.94102	-7.800624	-0.01113	1500	-16.0981525	-795.0478
584.46724	-7.828735	-0.01108	1550	-16.4889553	-814.6777
594.88515	-7.944132	-0.01096	1600	-16.8693841	-833.9585
615.19483	-8.166727	-0.0108	1650	-17.2459958	-852.8845
638.13869	-8.4146	-0.01054	1700	-17.6182797	-871.6069
693.21994	-8.995355	-0.01033	1750	-17.9870868	-890.1342
706.82229	-9.135886	-0.01028	1800	-18.3521941	-908.482
710.24495	-9.171076	-0.01025	1850	-18.7134633	-926.6414
716.94349	-9.239753	-0.0102	1900	-19.0709208	-944.6096
728.77658	-9.360453	-0.01016	1950	-19.425255	-962.4044
732.87758	-9.402103	-0.01011	2000	-19.7772528	-980.0627
747.45958	-9.549458	-0.01002	2050	-20.125528	-997.5695
765.36127	-9.728819	-0.00991	2100	-20.4707891	-1014.908
790.2808	-9.97578	-0.0097	2150	-20.8130839	-1032.097
854.3799	-10.59749	-0.00954	2200	-21.152634	-1049.143
861.98895	-10.67007	-0.0095	2250	-21.4892099	-1066.046
874.33424	-10.78731	-0.00943	2300	-21.8230616	-1082.807
892.16987	-10.95558	-0.00907	2350	-22.1548649	-1099.448
1070.1222	-12.56989	-0.00854	2400	-22.4840295	-1115.972
1231.9807	-13.95265	-0.00823	2450	-22.8110417	-1132.377
1312.1534	-14.61256	-0.00812	2500	-23.1358593	-1148.673
1328.9881	-14.74923	-0.00789	2550	-23.4575745	-1164.836
1533.4223	-16.36178	-0.00769	2600	-23.778028	-1180.89
1534.0815	-16.36685	-0.00768	2650	-24.0928548	-1196.772
1547.5186	-16.47001	-0.00764	2700	-24.4069935	-1212.496
1580.5452	-16.72219	-0.00757	2750	-24.7211322	-1228.203
1628.5824	-17.08564	-0.00749	2800	-25.0352708	-1243.91
1675.3816	-17.43604	-0.0074	2850	-25.3471729	-1259.561
1735.1383	-17.8784	-0.00731	2900	-25.6551504	-1275.058
1793.7289	-18.30688	-0.00723	2950	-25.9612231	-1290.409
1856.8444	-18.76292	-0.00714	3000	-26.2653152	-1305.663
1922.2987	-19.23007	-0.00705	3050	-26.56679	-1320.803
1996.07	-19.74987	-0.00697	3100	-26.8682648	-1335.876
2048.3453	-20.1141	-0.00691	3150	-27.1685215	-1350.92
2098.8929	-20.46318	-0.00687	3200	-27.4658086	-1365.858
2110.6119	-20.54369	-0.00685	3250	-27.7619759	-1380.695
2133.1646	-20.69818	-0.00683	3300	-28.0562567	-1395.456
2154.7916	-20.84579	-0.00679	3350	-28.3494085	-1410.142
2201.4446	-21.16244	-0.00673	3400	-28.6407712	-1424.754
2261.5713	-21.56708	-0.00666	3450	-28.9306322	-1439.285
2333.9015	-22.04888	-0.00658	3500	-29.2190108	-1453.741
2418.3231	-22.60466	-0.00652	3550	-29.5053303	-1468.109
2476.6712	-22.98481	-0.00648	3600	-29.7911823	-1482.413
2493.8251	-23.09598	-0.00646	3650	-30.0756463	-1496.671
2525.5897	-23.30113	-0.00641	3700	-30.358642	-1510.857
2605.4488	-23.81295	-0.00628	3750	-30.6404428	-1524.977
2828.9609	-25.21723	-0.00618	3800	-30.9208062	-1539.031
2876.6718	-25.51191	-0.00614	3850	-31.1999185	-1553.018
2926.5423	-25.81813	-0.0061	3900	-31.4778217	-1566.944
2987.002	-26.18694	-0.00603	3950	-31.754423	-1580.806
3129.5497	-27.04643	-0.00598		Total Area	-73026.76
3129.8895	-27.04847	-0.00598			
3140.0473	-27.10919	-0.00596			
3179.3048	-27.34322	-0.00592			
3258.8401	-27.81434	-0.00588			
3325.5947	-28.20669	-0.00585			
3342.0831	-28.30318	-0.00584			
3368.2505	-28.45598	-0.00582			
3396.5274	-28.62063	-0.0058			
3445.5011	-28.90468	-0.00577			
3509.2529	-29.27238	-0.00572			
3625.7046	-29.93814	-0.00566			
3720.2746	-30.47339	-0.00562			
3779.3153	-30.80519	-0.00559			
3838.3082	-31.13493	-0.00556			
3905.9132	-31.51069	-0.00553			
3959.3095	-31.80589				

z(x) = {zn^1.5 + An^1.5 (x-xn)}^2/3

Method 2 Profile A Predicted 1

x (ft)	z (ft)	coefficient	new x (ft)	new z (ft)	Area (ft^2)
115.013	0	-0.050287			
136.486	-1.079764	-0.029698			
154.431	-1.612703	-0.02524			
170.909	-2.028602	-0.022556	150	-1.4811092	
189.186	-2.440858	-0.020633	200	-2.6639796	-103.6272
205.778	-2.783198	-0.019162	250	-3.5934094	-156.4347
225.098	-3.153406	-0.017918	300	-4.3731503	-199.164
243.236	-3.478397	-0.017004	350	-5.0159629	-234.7278
257.625	-3.723061	-0.016404	400	-5.8322437	-271.2052
267.082	-3.878193	-0.015706	450	-6.3974495	-305.7423
279.389	-4.071484	-0.014903	500	-6.9404587	-333.4477
293.263	-4.278249	-0.014086	550	-7.4660663	-360.1631
308.011	-4.485994	-0.013402	600	-7.9746842	-386.0188
312.283	-4.543255	-0.013064	650	-8.4675848	-411.0567
329.373	-4.766515	-0.012256	700	-8.9497755	-435.434
345.462	-4.963695	-0.011518	750	-9.4189241	-459.2175
365.669	-5.196442	-0.010718	800	-9.873401	-482.3081
381.962	-5.371068	-0.010703	850	-10.317781	-504.7795
286.508	-4.349412	-0.014307	900	-10.746968	-526.6187
291.301	-4.417986	-0.014083	950	-11.159389	-547.6589
302.96	-4.582169	-0.013756	1000	-11.57181	-568.28
313.448	-4.726445	-0.013551	1050	-11.984231	-588.901
315.266	-4.751088	-0.012874	1100	-12.378286	-609.0629
391.727	-5.735459	-0.011698	1150	-12.759974	-628.4565
404.038	-5.879485	-0.011487	1200	-13.141661	-647.5409
413.89	-5.992652	-0.01121	1250	-13.516096	-666.4439
458.198	-6.489347	-0.010914	1300	-13.877658	-684.8438
481.664	-6.74546	-0.010797	1350	-14.228963	-702.6655
488.055	-6.814476	-0.010547	1400	-14.572564	-720.0382
544.359	-7.40833	-0.010235	1450	-14.916165	-737.2182
581.941	-7.792992	-0.010122	1500	-15.259767	-754.3983
584.467	-7.818562	-0.010081	1550	-15.597727	-771.4373
594.885	-7.923586	-0.00999	1600	-15.92267	-788.0099
615.195	-8.126482	-0.009871	1650	-16.245933	-804.2151
638.139	-8.352955	-0.009664	1700	-16.56737	-820.3326
693.22	-8.885271	-0.009514	1750	-16.887325	-836.3674
706.822	-9.014682	-0.009479	1800	-17.205824	-852.3287
710.245	-9.047123	-0.00945	1850	-17.522759	-868.2146
716.943	-9.110423	-0.009397	1900	-17.838191	-884.0237
728.777	-9.221621	-0.009346	1950	-18.152355	-899.7636
732.878	-9.259949	-0.009298	2000	-18.4656	-915.4489
747.46	-9.395532	-0.009208	2050	-18.777742	-931.0835
765.361	-9.560372	-0.009095	2100	-19.088799	-946.6635
790.281	-9.787021	-0.008888	2150	-19.398872	-962.1918
854.38	-10.35671	-0.008684	2200	-19.706116	-977.6247
861.989	-10.42278	-0.00864	2250	-20.010088	-992.9051
874.334	-10.52945	-0.008575	2300	-20.311021	-1008.028
892.17	-10.68238	-0.008248	2350	-20.609658	-1023.017
1070.12	-12.15021	-0.007634	2400	-20.905329	-1037.875
1231.98	-13.38579	-0.007231	2450	-21.198414	-1052.594
1312.15	-13.96554	-0.00707	2500	-21.488794	-1067.18
1328.99	-14.08457	-0.006872	2550	-21.776214	-1081.625
1533.42	-15.48945	-0.006544	2600	-22.062889	-1095.978
1534.08	-15.49376	-0.006535	2650	-22.346144	-1110.226
1547.52	-15.58157	-0.006512	2700	-22.628981	-1124.378
1580.55	-15.79663	-0.006479	2750	-22.911818	-1138.52
1628.58	-16.10785	-0.006447	2800	-23.194655	-1152.662
1675.38	-16.40958	-0.00641	2850	-23.477433	-1166.802
1735.14	-16.79259	-0.006374	2900	-23.759813	-1180.931
1793.73	-17.16607	-0.006339	2950	-24.040764	-1195.014
1856.84	-17.56614	-0.006304	3000	-24.319536	-1209.008
1922.3	-17.97876	-0.006267	3050	-24.595533	-1222.877
1996.07	-18.44106	-0.006244	3100	-24.87153	-1236.677
2048.35	-18.76745	-0.006221	3150	-25.145891	-1250.436
2098.89	-19.08191	-0.006219	3200	-25.416615	-1264.063
2110.61	-19.1548	-0.006209	3250	-25.686134	-1277.569
2133.16	-19.29482	-0.00618	3300	-25.953397	-1290.988
2154.79	-19.42849	-0.006141	3350	-26.219228	-1304.316
2201.44	-19.71499	-0.006078	3400	-26.483255	-1317.562
2261.57	-20.08041	-0.006001	3450	-26.746383	-1330.741
2333.9	-20.51446	-0.005913	3500	-27.008667	-1343.876
2418.32	-21.01368	-0.005832	3550	-27.269658	-1356.958
2476.67	-21.35396	-0.005786	3600	-27.530357	-1370
2493.83	-21.45321	-0.005763	3650	-27.790401	-1383.019
2525.59	-21.63626	-0.005734	3700	-28.049754	-1396.004
2605.45	-22.09413	-0.005657	3750	-28.30861	-1408.959
2828.96	-23.35848	-0.005654	3800	-28.566812	-1421.886
2876.67	-23.62823	-0.00564	3850	-28.82437	-1434.78
2926.54	-23.90952	-0.005595	3900	-29.081285	-1447.641
2987	-24.24779	-0.00552	3950	-29.337612	-1460.472
3129.55	-25.03464	-0.005451		Total Area	-68438.72
3129.89	-25.03649	-0.005448			
3140.05	-25.09183	-0.005432			
3179.3	-25.30506	-0.00539			
3258.84	-25.73379	-0.005336			
3325.59	-26.08996	-0.005301			
3342.08	-26.17737	-0.005287			
3368.25	-26.31572	-0.005278			
3396.53	-26.46497	-0.005264			
3445.5	-26.72278	-0.005246			
3509.25	-27.0572	-0.005214			
3625.7	-27.66438	-0.005187			
3720.27	-28.15492	-0.00517			
3779.32	-28.46018	-0.005155			
3838.31	-28.76429	-0.005138			
3905.91	-29.11167	-0.005125			
3959.31	-29.38532				

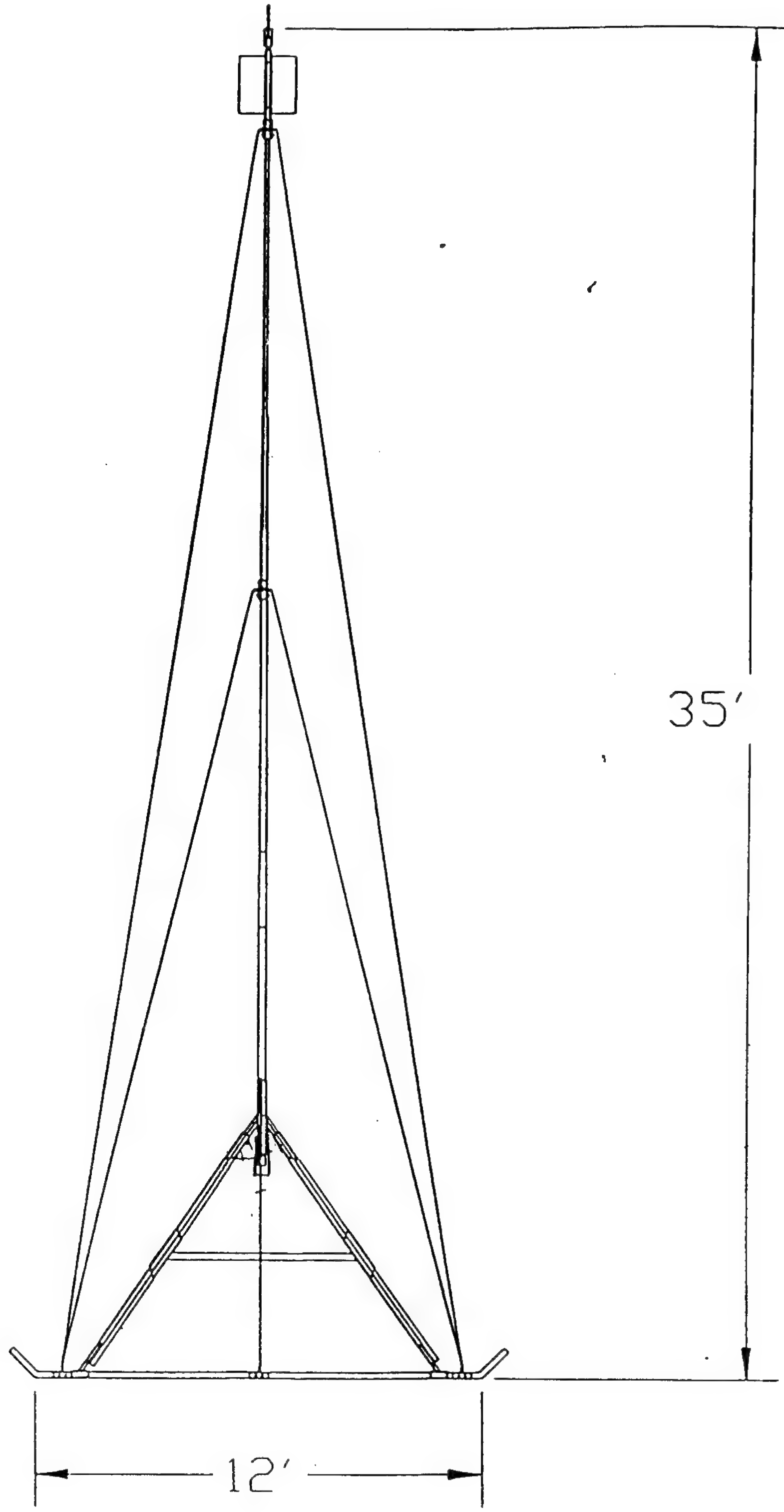
RMS of the distance
[(zpred-zmeas)^2]^.5

x (ft)	Method 1: z error (ft)	Method 2: z error (ft)
150	0.299	0.402
200	0.089	0.250
250	0.587	0.771
300	0.644	0.478
350	0.826	0.907
400	0.543	0.324
450	2.341	2.194
500	1.128	1.044
550	1.331	1.357
600	1.139	1.113
650	0.129	0.201
700	1.298	1.414
750	1.765	1.921
800	1.437	1.634
850	0.492	0.729
900	0.551	0.272
950	1.025	0.704
1000	1.499	1.137
1050	1.973	1.570
1100	2.094	1.647
1150	1.978	1.485
1200	1.861	1.324
1250	1.795	1.210
1300	1.818	1.183
1350	1.885	1.199
1400	2.101	1.364
1450	2.317	1.530
1500	2.533	1.695
1550	2.732	1.841
1600	2.918	1.971
1650	3.263	2.263
1700	3.453	2.402
1750	3.425	2.325
1800	3.503	2.356
1850	3.611	2.421
1900	3.638	2.406
1950	3.630	2.357
2000	3.619	2.307
2050	3.763	2.415
2100	3.475	2.093
2150	3.416	2.002
2200	3.932	2.486
2250	3.307	1.828
2300	3.233	1.721
2350	3.224	1.679
2400	2.977	1.398
2450	2.803	1.190
2500	2.748	1.101
2550	2.575	0.893
2600	2.437	0.722
2650	2.329	0.582
2700	2.223	0.445
2750	2.118	0.308
2800	2.012	0.171
2850	1.959	0.089
2900	1.911	0.016
2950	1.709	0.212
3000	1.485	0.461
3050	1.461	0.510
3100	1.437	0.560
3150	1.518	0.504
3200	1.545	0.505
3250	1.421	0.654
3300	1.407	0.696
3350	1.535	0.595
3400	1.779	0.378
3450	2.085	0.099
3500	2.450	0.239
3550	2.451	0.216
3600	2.371	0.110
3650	2.142	0.143
3700	1.756	0.553
3750	1.479	0.853
3800	1.465	0.889
3850	1.752	0.624
3900	2.144	0.252
3950	1.859	0.557
Total	158.96	84.46
Average	2.06	1.10

APPENDIX

C

Basic Sled Dimensions



Equipment Needed

1. Ten foot ladder

2. To tighten all bolts
   3/4" wrench
   3/4" socket and rachet

3. To tighten cables
   5/16" socket and rachet

4. Hammer

All Parts are located above room 117 B in the hydrolab:

Pole A
Pole B
Pole C
Yoke
Skids 1 & 2
Leg 1A
Leg 2A
Leg 1B
Leg 2B
Red brace
White brace
GPS box
Triple prism connector

Sled Locker is located outside room 117B near the door.

Weights of Sled Pieces

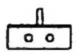
Poles:	
A	9.5 lb.
B	10.5 lb.
C	29.0 lb.
Braces:	
Front Brace (red)	24.0 lb.
Back Brace (white)	24.0 lb.
Back Plates	3.5 lb.
Legs:	
1A	43.0 lb.
1B	43.5 lb.
2A	43.0 lb.
2B	43.0 lb.
Skids:	
1	35.75 lb.
2	35.75 lb.
Others:	
GPS Box	28.0 lb.
Yoke	22.5 lb.
Tree	5.5 lb.
Cable Connection:	
To Skids	3.5 lb.
To Pole	3.0 lb.
GPS Antenna	2.5 lb.
Triple Prism	4.0 lb.

P-C

Pole to Cable Connector (P-C):
P-C is bolted to Pole A & Cable connects to loops

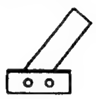
TREE

Tree: Cables are connected to tree located in the middle of pole B. Side Cables run through arms to stop cable from swaying



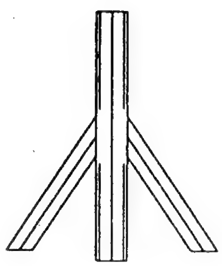
S-C

Skid to cable connectors (S-C):
S-C is bolted to skid & cable is connected to loop on top of S-C.



S-L

Skid to leg connector (S-L):
S-L is bolted to the skid & then the legs bolt to S-L

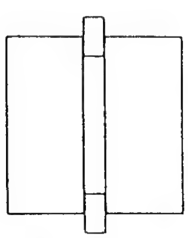


YOKE

Yoke: the legs connect to the yoke & pole C is bolted to the sleeve on top of the yoke

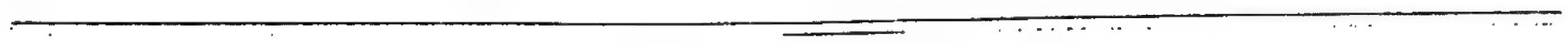
GPS A

GPS antenna connector (GPS A):
GPS antenna is screwed onto the threaded shaft & connector is pinned to pole A



GPS BOX

GPS Box: the GPS battery & Data Processor are placed inside the box. The box is pinned onto pole A



POLE A

Pole A is 14 ft long with 1.25" outer diameter. The top has 5 pairs of holes in it.

POLE B

Pole B is 12 ft long and has a outer diameter of 1.75"

POLE C

Pole C is 11 ft long and has a diameter of 2.25"

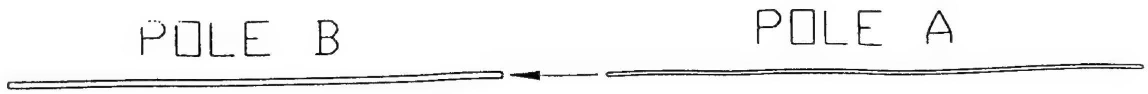
LEG

There are 4 legs labeled 1A, 2A, 1B, 2B

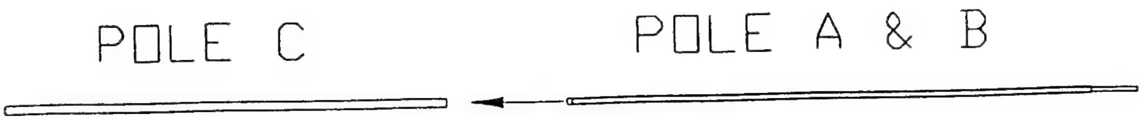
SKID

There are two skids marked 1 & 2

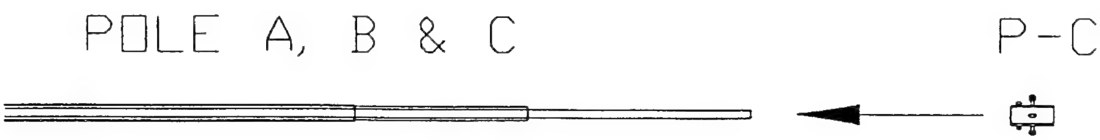
Steps for assembly



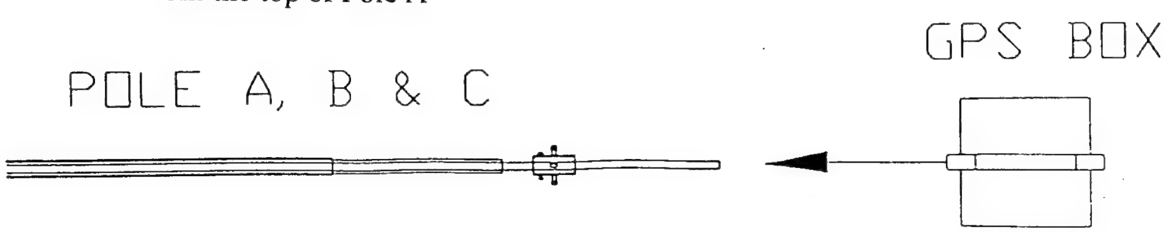
1. Insert Pole A into Pole B



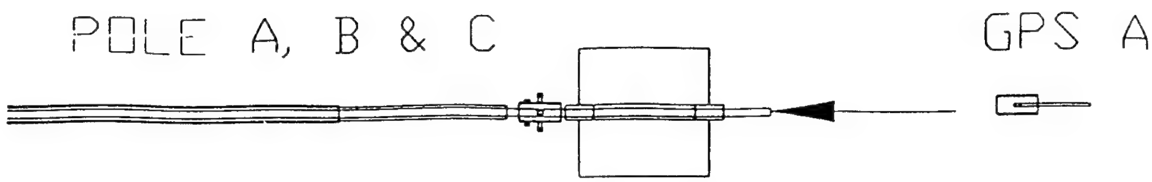
2. Insert Poles A&B into Pole C



3. Bolt P-C to Pole A with the 3" bolts (purple paint) at the 4th and 5th hole from the top of Pole A



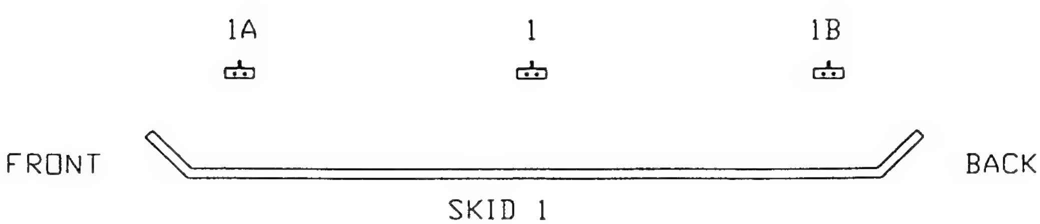
4. Bolt the GPS Box to the 2nd and 3rd holes from the top of Pole A with the stainless steel pins and cotter pins



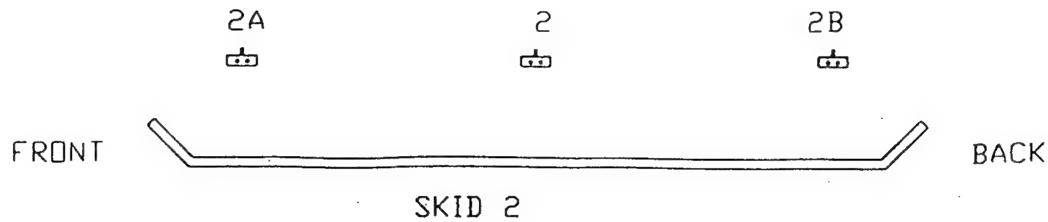
5. Attach GPS A to the first hole from the top of Pole A with stainless steel pin and cotter pins

6. Insert Poles A, B, and C into the yoke

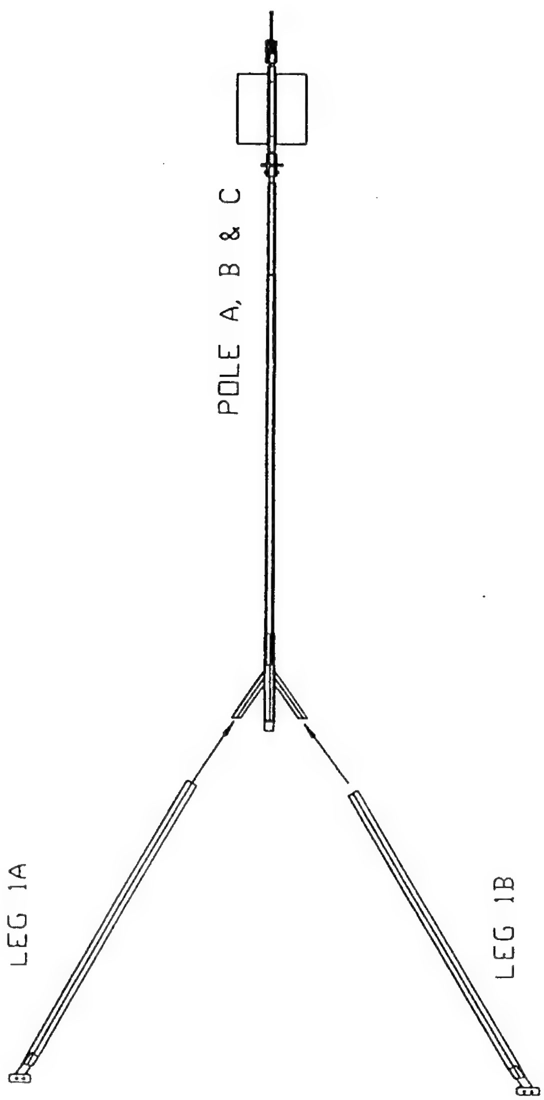
Skids:
The skids are labeled 1 & 2. With skid #1 on the left and #2 on the right



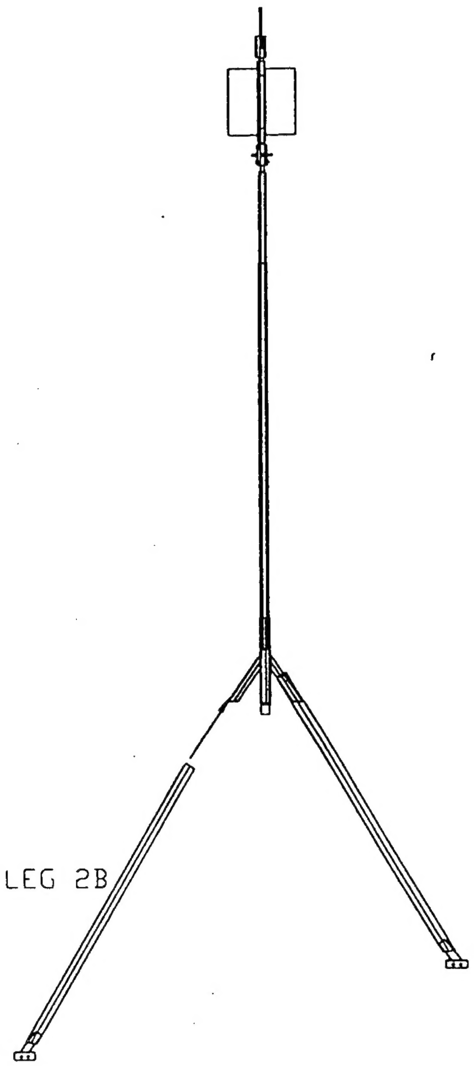
7. Attach S-C 1A, S-C 1, & S-C 1-B to skid 1 with the 6" bolts (Bronze paint). S-C 1A should be placed at the front of the skid, while S-C 1B should be placed at the center of skid 1. S-C 1 should be placed at the center of skid 1.



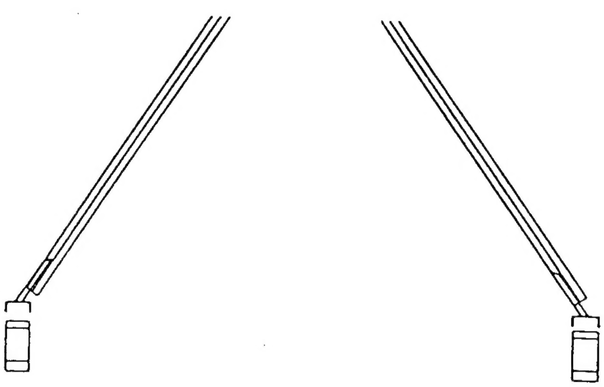
8. Attach S-C 2A, S-c 2, & S-C 2B to skid 2 with 6" bolts. S-C 2A should be placed at the front of the skid, while S-C 2B should be placed at the center of skid 2. S-C 2 should be placed at the center of skid 2.



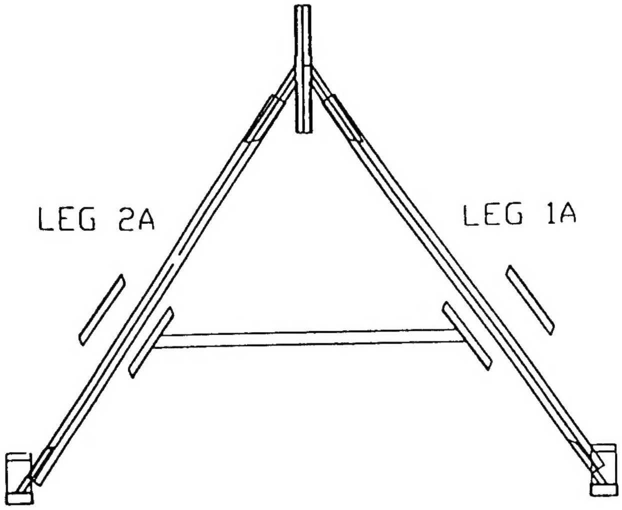
9. While the Yoke & Poles A, B, & C are on the ground, attach leg 1A & leg 1B to the yoke. The extensions of the yoke are labeled 1A, 1B, 2A, & 2B. Make sure the legs are placed in the correct extension. Use the 3.5" bolts (white paint) to attach the legs.



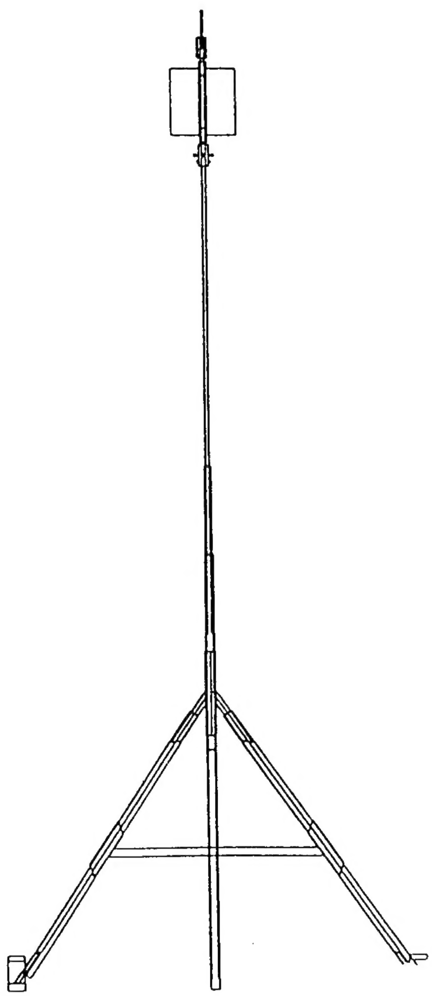
10. Raise the yoke up & attach leg 2A & leg 2B with the 3.5" bolts (white paint) to the yoke.



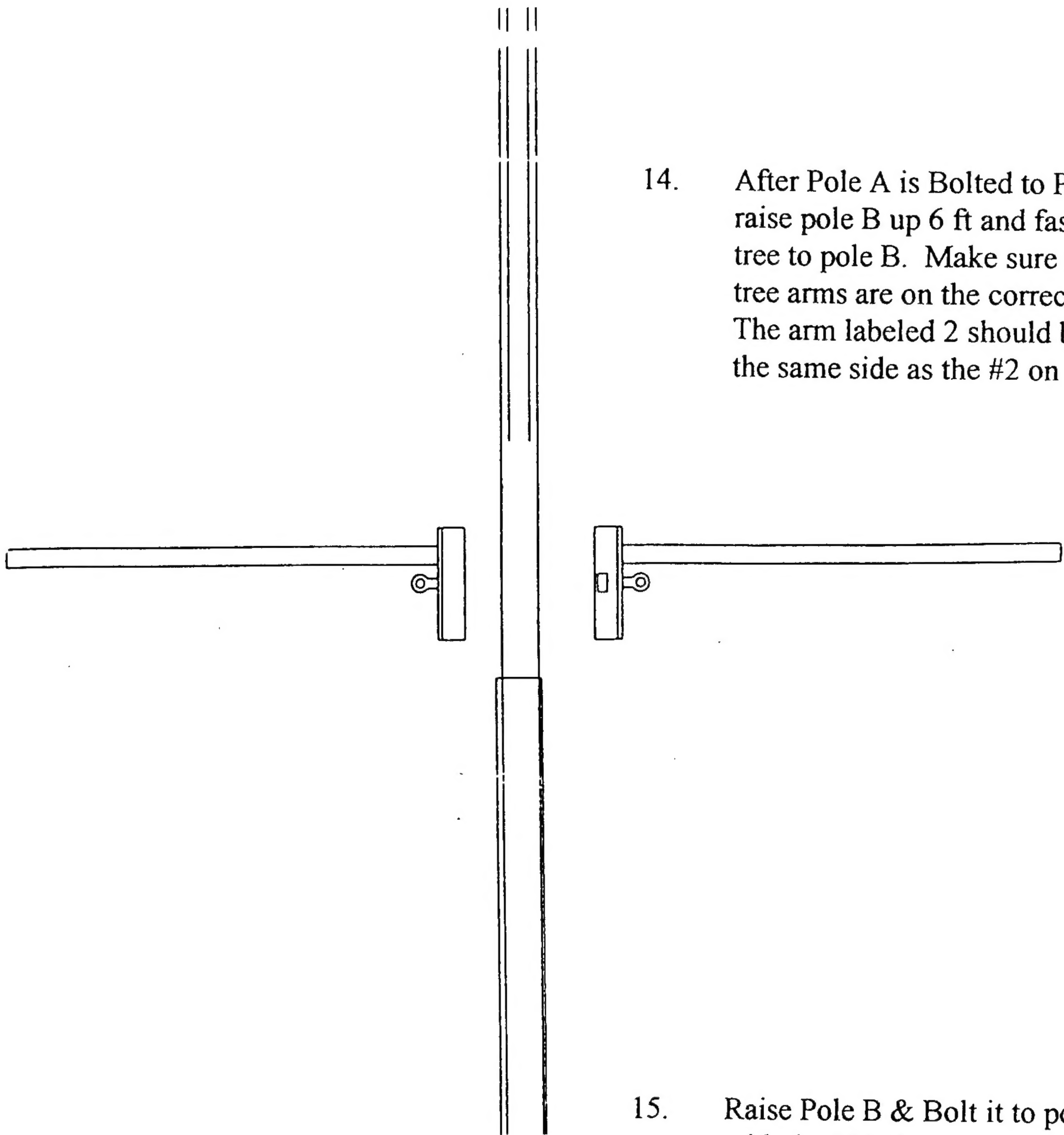
11. After the legs are bolted to the yoke, the legs should be fastened to the skids with the 6" bolts (bronze paint)



12. Attach the braces to the legs using the 4" bolts (red paint). Each side of the brace is labeled to indicate which side goes to which leg. Each of the brace backs are also labeled.

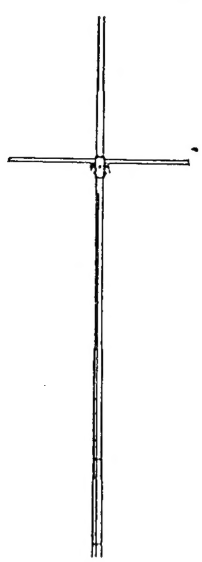


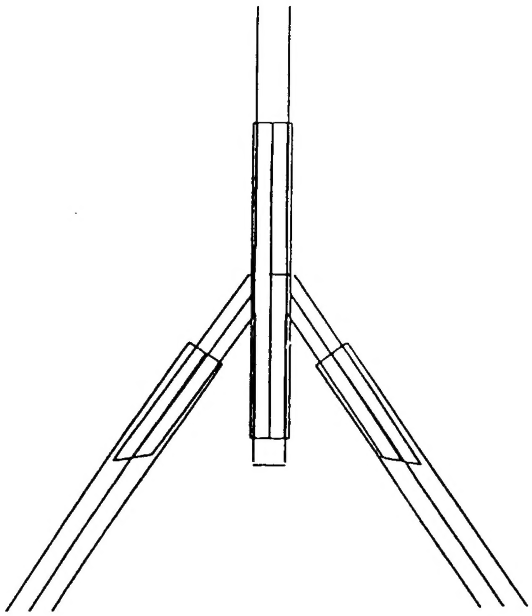
13. A ten foot ladder will be needed to raise and bolt Pole A with the purple bolts.



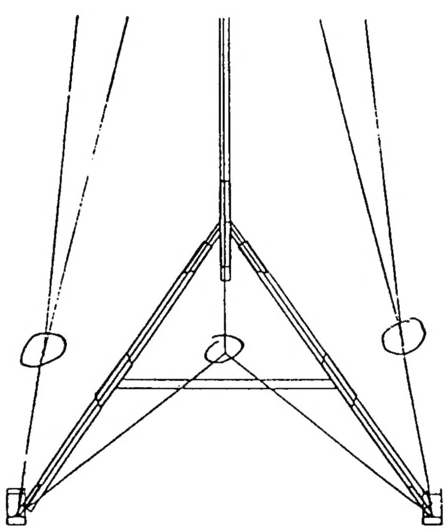
14. After Pole A is Bolted to Pole B, raise pole B up 6 ft and fasten the tree to pole B. Make sure that the tree arms are on the correct side. The arm labeled 2 should be on the same side as the #2 on pole A.

15. Raise Pole B & Bolt it to pole C with the 3" bolts.





16. Raise pole C up and bolt into place with the 3" bolts. The bottom of Pole C should be 6" below the yoke.



17. Fasten the four turnbuckles with the same colors together. The cables may need to be adjusted to ensure the top is level. A 5/16" rachet and socket will be needed for this.